PRODUCT ENGINEERING

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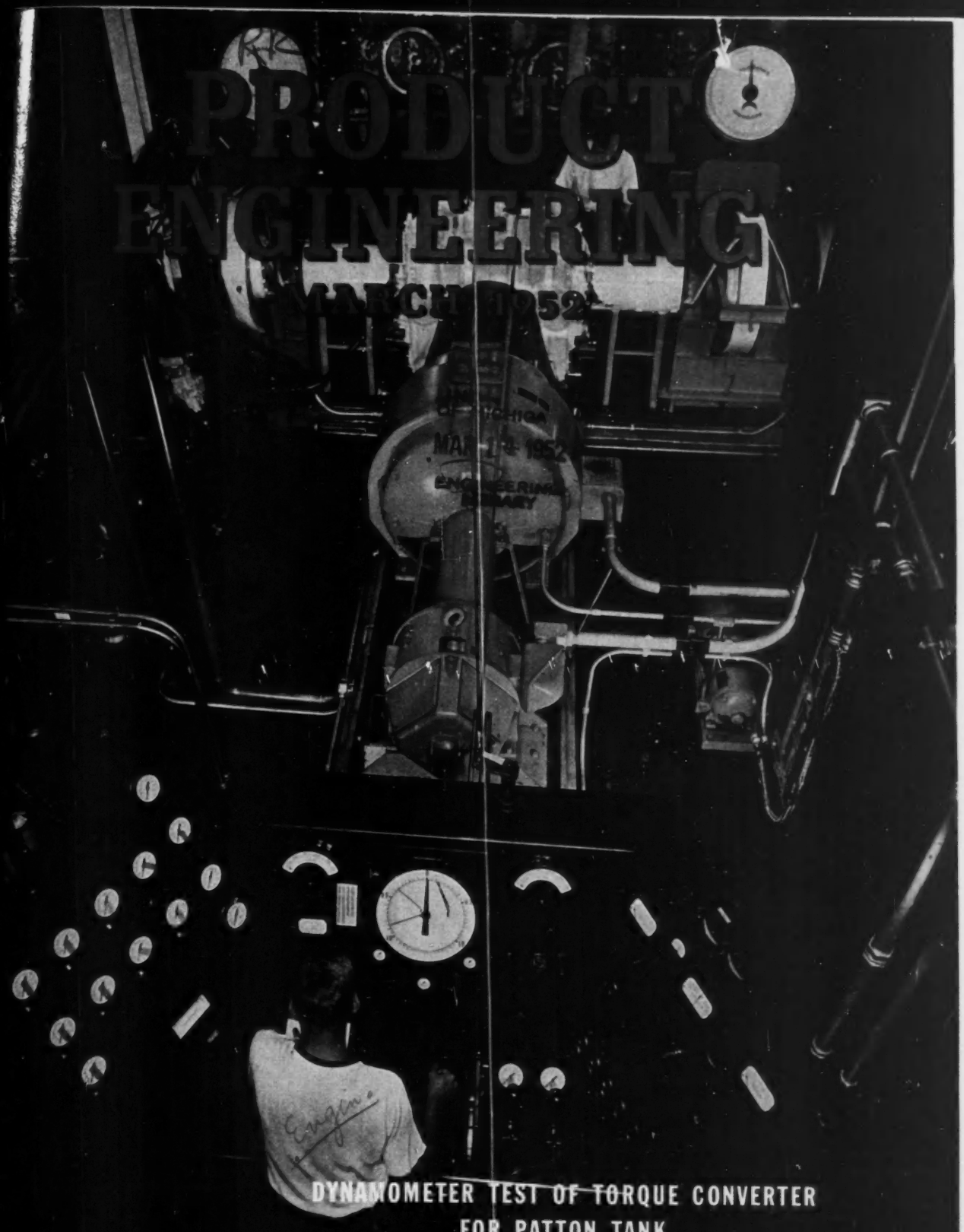

DYNAMOMETER TEST OF TORQUE CONVERTER FOR PATTON TANK

IN THIS ISSUE—Rubber Springs + Fixed Resistors + Torsional Fatigue Failures + Integral Horsepower d-c Motors + Fitting Machines to Men

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FIVE DOLLARS A YEAR

STAINLESS STEEL FOR SUBSTITUTIONS

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Sharon, Pennsylvania

VOLUME 23 **PRODUCT ENGINEERING** NUMBER 3

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to do the whole job for you

There are three reasons why you get unequalled contact assembly performance when you put Mallory assembly engineering to work for you.

Mallory *facilities* are unexcelled. Mallory *personnel* is unequalled, both from the standpoint of training and practical achievement. And Mallory *experience* is invaluable—covering development of exclusive new alloys . . . designs . . . fabricating and finishing methods . . . brazing techniques.

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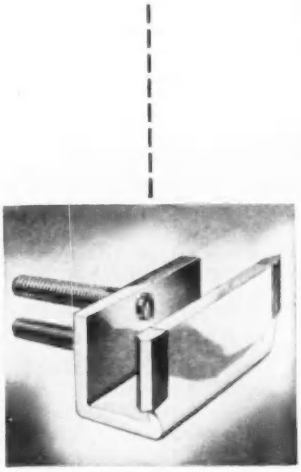

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Highlights

When requesting further information from companies and organizations mentioned in the items below, confusion can be avoided by referring to the issue of Product Engineering in which items appear

NONMETALLIC MATERIALS

RADICAL DEPARTURE from ordinary heat resistant paints is improved Heat-Rem H-170 made by Speco Inc. of Cleveland. New silicone-base formulation withstands temperatures up to 1,700 F and forms a bright elastic finish that resists moisture, corrosion, mild acids and alkalis.

LOSS OF STRENGTH in glass fiber reinforced plastics after prolonged water immersion is reduced from about 40 to 10 percent when Owens-Corning Fiberglas' finish No. 136 is used. The chemical treatment produces a strong, waterproof bond between the polyester resin and the reinforcing Fiberglas fabric. Resulting laminate has flexural strength of 60,000 psi after 30 days immersion in water.

BLACK VINYL PRIMER adheres well to brass, polished chrome, stainless steel, glass, aluminum, zinc plating and molded phenolics. Its extreme flexibility allows parts to be formed, extruded or blanked after being finished. United Lacquer Mfg. Corp. of Linden, N.J., reports this VB282 primer air dries in 15 min. In addition, it resists salt spray, humidity, abrasion and most of the solvents.

"VERSATILE" is about the best way to describe duPont's new Mylar polyester film. It combines a tensile strength of 25,000 psi with good dielectric properties throughout the temperature range from 392 F down to -58 F. Impact strength is at least twice that of any known commerical film.

QUICK-DRYING, synthetic coating that can be used safely on acrylic resin products has been developed by Neehi Protective Coatings, Inc. of Lindenhurst, N.Y. NE 108 can be painted on Lucite and similar materials without crazing them, proceding an opaque surface. One promising use is for blocking off light in specific areas on the faces of illuminated panels.

NEW ADHESIVE for joining silicone rubber to steel in a permanent bond "stronger than the rubber itself" is one of General Electric's recent developments. This glue-like preparation will form a bond in applications such as shock mounts for engines; will withstand temperatures from -85 to +500 Fahrenheit.

HIGH TEMP GREASE for ball, roller and plain bearings remains stable to 300 F for continuous operation and to 350 F during intermittent service. The Texas Co. also claims good oxidation and water resistance, as well as efficient performance at high operating speeds.

METALLIC MATERIALS

EXTENSIVE DEPOSITS of monazite, a mineral containing thorium, extend 700 miles through the south eastern states, according to a U.S. Geological Survey. Exact extent of the deposits is not available because thorium is an atomic energy raw material. The thorium can be converted into a fissionable source of uranium by neutron bombardment, thus supplementing present supply.

"MASSIVE" VANADIUM having a purity of 99.8 percent is being produced by calcium reduction of vanadium trioxide. Studies at Union Carbide's Division, Electro Metallurgical Co., indicate the material can be hot worked into ductile wire or sheet that has good resistance to salt water. Other properties are high elastic modulus, negligible magnetic susceptibility, and weldability by shielded arc methods.

A LITTLE MISCH METAL – about 50 percent cerium, 25 percent lanthanum and balance other rare earth metals plus iron – increases the creep resistance of manganese-magnesium extrusion alloys. According to tests at Battelle Institute, effect of these additions appears to be greatest at 600 F where the ultimate strength is increased from 4,000 psi (no Misch metal) to 10,200 psi for additions of approximately two percent.

(continued on page 7)

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IF YOUR PROBLEM IS
BEVEL GEAR OR CURVIC COUPLING DESIGN
MANUFACTURING EQUIPMENT
PRODUCTION TIME AND COSTS
To help you . . .
THE DESIGN ENGINEER should provide us with preliminary layouts or prints of proposed bevel gear designs . . . type of drive, horsepower and speed . . . type of loading (constant, intermittent or shock) . . . type of material . . . driving member and direction of rotation.
THE PRODUCTION ENGINEER should furnish blue prints, material specifications, manufacturing tolerances . . . quantity of gears to be produced . . . number of working hours available for production.
Every day highly skilled engineers within our organization provide the answers to these problems. Backed by the company's 85 years' experience in this field, our complete engineering service is at your disposal, without obligation, to study any bevel gear or Curvic coupling design problem you may have. We will be glad to make our recommendations as to the best design, the proper equipment and the most advantageous methods for reducing production time and costs.
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STABILIZED PHYSICALS mark a new aluminum-base casting alloy as having considerable promise. The addition of less than a half percent of titanium and manganese to formulations containing three to eight percent magnesium is key factor. Acme Aluminum Alloys of Dayton holds patent.

TITANIUM PRODUCTION has reached the rate of 1 1/2 tons per day and duPont predicts this figure will jump to 2 1/2 tons before long. Considering commercial production in 1948 was only 100 lb per day, this rate of acceleration presages a rapid increase in the year ahead.

STAINLESS and other high alloy steels containing less alloy materials, metals able to withstand extreme heat or corrosive conditions, are among objectives of an intensified research. A Committee of Stainless Steel Producers working with the American Iron and Steel Institute is coordinating this important project.

PROCESSES

BETTER PERMANENT MAGNETS may result from a process held by GE. The magnets are cast in cavities in which heat loss through the sides during solidification is held to a minimum. A metal chill in contact with one end of the molten alloy pulls heat out and causes long crystals to form.

ORANGE PEELING of stretch-pressed aluminum alloy sheet is apt to occur on the super-annealed material and then only if the sheet is subjected to plastic deformation of 10 percent or more while in this condition. Tests at Haviland Aircraft, Hatfield, England indicate the answer is to anneal at 275 to 325 C for one hour prior to forming.

GLASS LUBRICATION is the unique feature of the Ugine-Sejournet hot extrusion process now being used by Babcock & Wilcox at Beaver Falls, Pa. Company spokesman claims hollow and solid sections made of "unforgeable" materials are now producible and that sections can be complex.

POROUS STEEL may give cast iron some competition. Technique worked out at Toronto's Ontario Research Foundation permits variation of density from 92.5 to 453 lb per cu ft. Method is a close relation to powder metallurgy. Dimensional accuracy of "porous" parts is intermediate to that of cast iron and powdered metals.

TORCH BRAZING is successful only with certain of the aluminum alloys, according to Reynolds Metals Co. These are 2S-0, 3S-0, R355-0, R355-T6, 63S-F, 63S-T5 and 63S-T6. Copper-bearing alloys 11S, 14S, 17S and 24S are impractical because of losses in corrosion resistance and mechanical properties. And the magnesium-bearing compositions like 52S and 56S require special techniques to avoid oxidation.

LIMITING THE MOVEMENT of atoms in the crystal lattice of metals is the basis of a process developed by the Metalloid Corp. of Huntington, Ind. for cutting the hard-to-machine materials. Nascent atoms are fed to cutting surfaces from a compound mixed with the coolant. Atoms "freeze" the top molecular layer and create a brittleness that reduces plastic deformation and heating.

ELECTROPLATING a uniform non-porous coating of aluminum on steel from a fused aluminum chloride--sodium chloride salt bath is one of Alcoa's latest developments. Optimum current density is 15 amp per sq ft; lower current densities produce smoother but less adherent deposits. Rate of deposition is about 0.3 gram per amp-hr and the efficiency about 80 percent.

COMPONENTS

NEW SHUTTER for aerial cameras makes it easier to spot ground details at greater flying speeds. Fairchild Camera and Instrument Corp's Rapidyne has two sets of blades. One set opens and the other closes, almost at the same instant, thereby increasing efficiency of the shutter and producing clearer pictures for same exposure.

COILED TUBING made of Alcoa's new B50S-0 aluminum alloy is both economical and has several desirable features. Utilitube is easily worked, has high fatigue strength and good resistance to vibration, corrosion and low temperatures. Tubing handles all refrigerants except methyl chloride.

A FRENCH LOUDSPEAKER under study at the Institute of Inventive Research, San Antonio, produces sound waves with virtually no distortion. This "Ionophone" can reproduce all sound, including that in ultrasonic ranges, with high fidelity and efficiency because electrical energy is not translated into sound mechanically.

(continued on page 9)

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Another development using

B. F. Goodrich Chemical Company *raw materials*

THIS silverware container is used in an automatic dishwasher, and it saves *plenty* for both the housewife and the manufacturer. Molded from a Hycar rubber-phenolic compound, it replaces containers made of brass screening. Its surface is so smooth that it won't scratch the finest silverware. It withstands the action of hot water and detergents—has a long life. It's sturdier and tougher than brass screen types, stands up far better under rough handling in assembly or shipping—an important manufacturing economy.

GENTLE WITH SILVERWARE -YET TOUGH AS THEY COME!

Hycar-phenolic compounds have many advantages that help improve products, bring cost-savings too. They impart extra toughness and shock-resistance that enable molded parts to withstand more than usual abuse. In processing, they provide better molding characteristics . . . easier flow in the mold than straight phenolics . . . resistance to cracking around metal inserts in the part.

One of the many Hycar rubber compounds may be just what you need to solve a product problem. For versatile Hycar is used as a base material . . . as a modifier for phenolic resins . . . as a plasticizer for polyvinyl resins . . . as an adhesive base . . . as a latex for coating or impregnating. For helpful technical bulletins and advice, write Dept. HP-2, B. F. Goodrich Chemical Company, Rose Building, Cleveland 15, Ohio. Cable address: Goodchemco.

B. F. Goodrich Chemical Company
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Hycar-phenolic compound supplied by General Electric Company, Chemical Division, Pittsfield, Mass. Basket molded by Prolon Plastics Co., Florence, Mass. B. F. Goodrich Chemical Company supplies the Hycar American rubber only.

Hycar
Reg. U.S. Pat. Off.
American Rubber

GEON polyvinyl materials • HYCAR American rubber • GOOD-RITE chemicals and plasticizers • HARMON organic colors

SWITCHING TUBE functions in a few millionths of a second. GE engineers say the tube decouples a radar transmitter from a common transmitting and receiving antenna to permit the antenna to receive the return signal after a radar signal is sent. Speed in the switching operation is necessary to attain full sensitivity of the system for spotting objects that are nearby.

A TINY THERMOSTAT made by Thomas Edison, Inc., W. Orange, N.J., is smaller than a paper clip. It has a temperature range from -50 to +350 F, and should find wide use as a heat control in crystal ovens, hot plates and heating pads.

BURIED IN THE HEAD of an ordinary threaded fastener, ceramic capacitor has several advantages. Designed by Sprague Electric Co. of N. Adams, Mass., for VHF and UHF use, button type units have low ground inductance of fixed value, short and radially uniform by-pass path to ground.

FOR FASTEST RESPONSE, the circuit of the Bureau of Standards magnetic clutch should be laminated. Analysis shows that the torque-to-inertia ratio is maximized, favoring fast response, if the inertia of the clutch output disk equals three times the load inertia.

TESTING

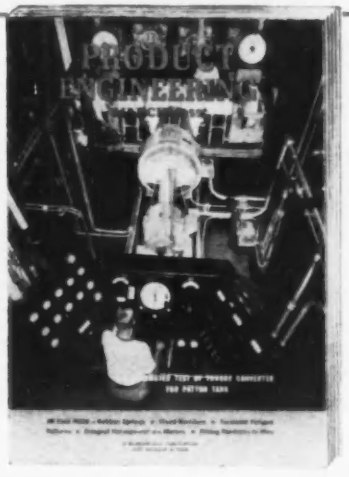
NEW ASTM STANDARDS are now being published for nodular or ductile cast iron. Also in the 1951 Supplements are approved changes in the Specs for magnesium-base alloy permanent mold castings. The latter include temper designations to conform with current commercial practice.

LETTING RESEARCHERS SHARE in commercial success of projects is a remarkable aspect of Horizons, Inc., Cleveland. When project reaches commercialization stage, a company owned in part by staff members who worked on the development is incorporated. A percentage of ownership is then offered to outside manufacturers.

IMPROVED, NON-TOXIC Dy/Chek formula for parts inspection has been worked out by Turco Products Inc., Los Angeles 54. Basically a "hide and seek" process, a red dye is applied to the surface and allowed to "hide" in any flaw or defect. Dye is then removed and a white developer applied. As the latter dries, it "seeks" the "hidden"dye and pulls it to the surface.

A "WATER TABLE" for studying shock wave patterns beyond the sonic barrier, such as those set up by supersonic jets and guided missiles, has been constructed for the engineering department at the University of Tennessee. The model will be used for teaching future engineers the principles of supersonic flow. It is capable of producing data on effects of speeds as high as 2,500 mph.

A NEW SYSTEM for measuring accurately the air consumption of single-cylinder test engines is the result of studies at GM Research Labs. It makes possible the maintenance of constant inlet air pressure, temperature and humidity independent of prevailing atmospheric conditions. Accurate to one percent under all operating conditions, technique utilizes the principle of critical or sonic flow of gas through a convergent nozzle. Other systems, which use conventional orifice meters, may result in an accumulation of errors that total as much as 20 percent.



THIS MONTH'S COVER

Testing the Allison CD-850 General Patton Tank transmission. This 3000-pound unit, which is a combination mechanical hydraulic torque converter unit, is run on a test stand for a minimum of two hours, at which time every function of the transmission is checked. This includes the input torque, total torque, brake check and check for leaks, pump operation, pump pressures, and left and right steering mechanism. Approximately five minutes of the total running time of two hours is at 2800-maximum rpm. After each transmission goes through test procedure, it is in perfect condition and ready for installation in the Patton tank. The same precision is used in the manufacture of the CD-850 as is used in aircraft engine manufacture and test.

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Can You Use a HEAVY liquid?

Can you use a heavy liquid that has contributed greatly to simplifying design and fabrication of certain products?

Acetylene tetrabromide is an unusually heavy liquid with a specific gravity of 2.95. In the absence of sunlight, acetylene tetrabromide is stable in dry air. And, when sealed in an opaque container, it will not break down.

Acetylene tetrabromide is comparatively inexpensive and finds wide use as a gauge fluid and as the movable part in vibration dampeners. It is also used for mineral separation by specific gravity.

GIVE A SEARCHING LOOK at the properties of acetylene tetrabromide. Then, if you desire further information or technical service, write or wire Dow.

$C_2H_2Br_4$ →

Properties:

Clear, colorless liquid with a mild sweet odor.

Specific gravity at 25/25°C.	2.953
Pounds per gallon at 25°C.	24.57
Boiling point at 15 mm. Hg	119°C.
Freezing point	0.0°C.
Fire point	None
Flash point	None

Solubility, grams per 100 grams solvent:

Alcohol at 25°C.	∞
Carbon Tetrachloride at 25°C.	∞
Chloroform at 25°C.	∞
Ether at 25°C.	∞
Water at 30°C.	0.065
Water at 80°C.	0.28

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FOREIGN NEGOTIATIONS

The United States is bartering wherever it can for strategic and short supply metals. Negotiations are going on with the Belgians for industrial diamonds, with other nations for columbium. The recent conference between Prime Minister Churchill and President Truman produced an exchange of U.S. steel for Malayan tin and Canadian aluminum. The U.S. has also bought twenty-five thousand tons of raw rubber from the British to put into our defense stockpile.

In exchange for one million tons of steel--80 percent in ingots from the U.S., the rest in scrap and pig iron bought abroad and deferred to the British--the United States will get twenty thousand tons of tin, priced at $1.18 a pound. Canada is giving the U.S. thirty-three million pounds of aluminum, to be paid back next year out of new U.S. production capacity. This exchange is in addition to twenty-two million pounds already contracted for. The U.S. is also working on an arrangement to get some copper from Canadian sources.

DEFENSE SLOWDOWN

Washington still hasn't all the answers on the effects of the slowdown of military production. But one fact now is clear despite the fog of confusion: there will be cancellation of some prime contracts and many more subcontracts. It means a shift in future plans. But no one in the armed forces, or anywhere else in Washington, can tell precisely what contracts and subcontracts will be killed or changed.

Officially, the explanation for the slowdown is that we have become strong enough in the eighteen months since Korea to tinker a little more with design-to get a much better jet plane than the Mig-15; better tanks, guns and other equipment than the Reds. The economy can much better stand the impact of two or three fifty billion dollar military budgets than one, perhaps two, of more than seventy billion.

The services have been extremely hesitant to freeze specifications for any new weapons, out of a very healthy dread of obsolescence. But they still seemed bent on making a delivery record at the same time. The civilian mobilizers have been just as reluctant to cut back auto, appliance and other civilian goods production. They would have had to slash materials for civilian products farther than ever in July if the military had won its seventy-one billion dollars.

CIVILIAN GAINS

It is hard to calculate the precise benefits that will accrue to civilian production out of the military slowdown. There will be some gains, starting in the second quarter, when one million pounds of aluminum above their scheduled April-June supply will be alloted to automobile producers. A smaller amount will be distributed among other consumer goods manufacturers.

The extra aluminum will come from approximately thirty-nine million pounds being taken out of previously set allotments for the Air Force for the quarter. But the rest of the big turnback will be used to fill out first quarter allotments for which producers, mainly of military items, are now unable to fill orders. The same goes for most of the more than ten million pounds of stainless steel also being turned back by the Air Force in the second quarter. But there will be little or no extra copper.

(continued on page 115)

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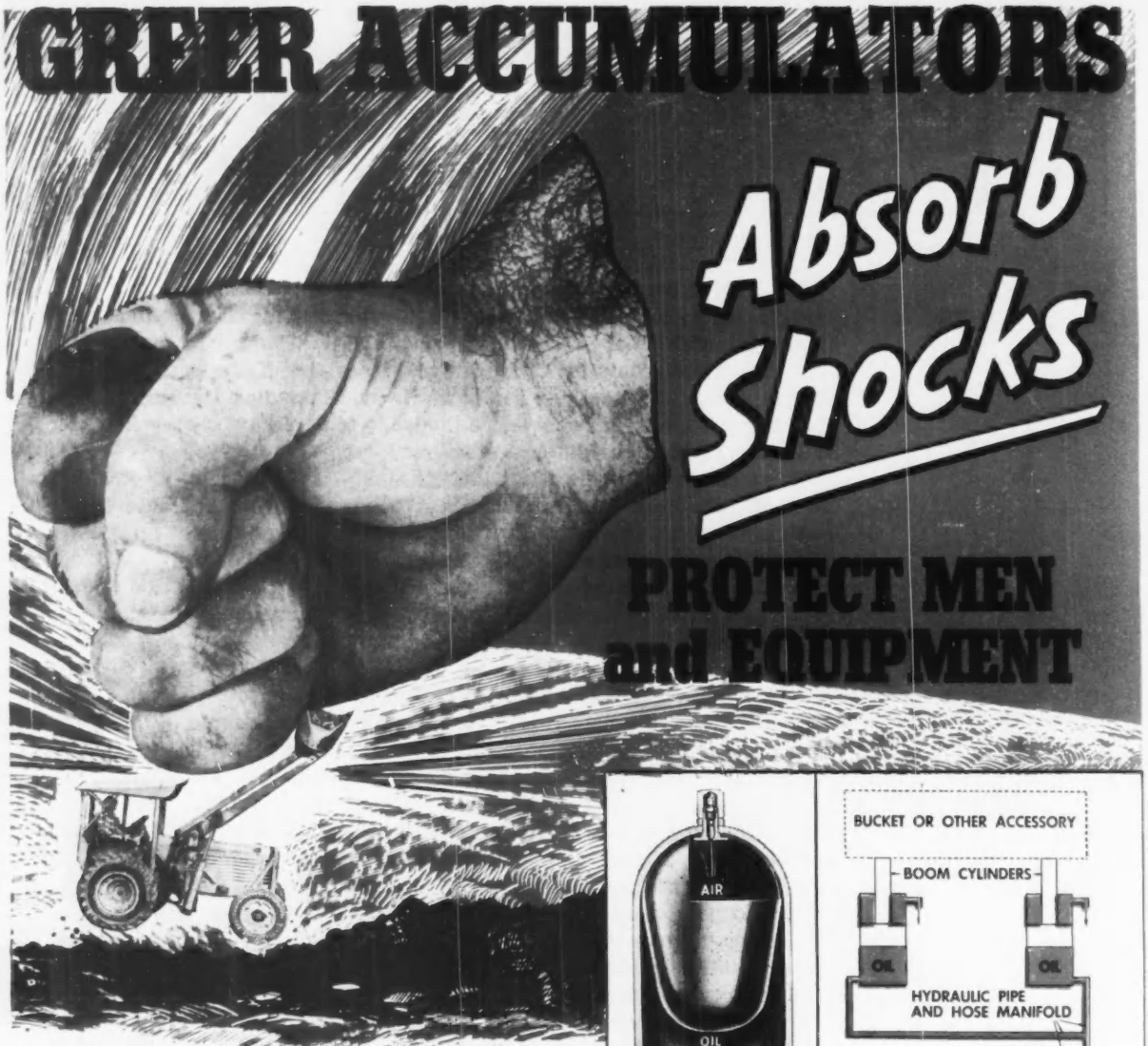
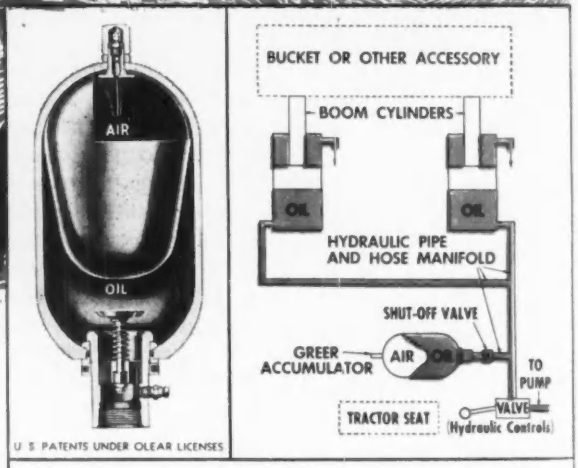
GREER ACCUMULATORS



■ Shock and vibration increase the maintenance cost and reduce the life of hydraulically operated equipment. A Greer Accumulator absorbs these shocks to an amazing degree. It prevents structural fatigue, increases life of components, permits operators to work in comfort, and greatly increases productivity of equipment.

Various Greer bulletins cover specific solutions of shock and vibration problems, including line shock suppression, pulsation dampening, and shock absorption on various types of equipment. Write us your problem.



Bucket loaders, power shovels, and other tracked or rubber-tired machines equipped with a Greer Accumulator are free from destructive as well as nerve-racking shock and vibration caused by rapid changes in momentum of the loaded bucket, or when traversing rough ground. Schematic diagram shows a typical application. Section shows simplicity of a Greer Accumulator.

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GREER
ACCUMULATORS

Civilian allotment rates for the rest of 1952 probably will come close to the level already set for the second quarter. This means most producers of civilian goods will get about fifty percent of their pre-Korea steel, twenty-five to thirty percent of the aluminum, eighteen to twenty percent copper. Next year, possibly in the last two quarters of 1952, supplies of steel and aluminum will become more plentiful for the consumer goods maker. By then he'll be getting metal from new production plants as well as from the military cutback.

APPLIANCE REDESIGN

The mobilization pinch on raw materials is forcing redesign of appliances. Manufacturers have gone about as far as they can in cutting use of critical materials by easy production switches--doing away with gadgets and trim, substituting more available materials for critical metals in parts and surface features. But for the rest of 1952, at least they are going to have to cut back even further on use of some key materials.

Nickel is needed in increasing quantities for jet aircraft and ordnance because of its heat-resistant and hardening qualities. Appliance makers have made drastic cuts in their use of this scarce metal: to forty-three percent of pre-Korea consumption for electric kitchen ranges, forty-five percent for washers, thirty-five percent for refrigerators.

CONSERVATION EFFECTS

One company reduced its nickel use ninety pounds per 1,000 refrigerators by using chrome steel instead of nickel stainless for shelves and other exposed parts. Another refrigerator maker went even further, saving 149 pounds per 1,000 units by using enameled steel and chrome, and eliminating all nickel plated and stainless parts. Savings by electric range makers amount to 1.43 pounds per range overall. But they are nearing the end of their rope on savings of this type. Without redesign, nickel is essential for range heating units as well as for heating elements in dryers, ironers and other products. There has been almost as much conservation of copper, which is just slightly less scarch and about as essential for appliances as nickel. One producer of electric ranges rewired all his lines to save copper wire. Another redesigned valves and fittings to save eighteen to fifty percent of the brass used for each. A refrigerator maker saved 3,500 pounds of copper per 1,000 units by cutting sheet thicknesses and eliminating some copper entirely from other parts.

The same story is true for aluminum. A manufacturer of home washers reduced his aluminum use last year by 150,000 pounds by using cast iron instead of aluminum die castings for motor end bells. Another saved 40,000 pounds by using plastic instead of aluminum agitators. Most washer makers have substituted enameled steel for aluminum sheet in many parts. But you can't take much more critical material out of appliances by this kind of direct substitution and simplification of parts. Next step is to design substitute materials into an entire product.

MILITARY COMPONENTS

Military, atomic energy and defense requirements for components are increasing steadily and so are material troubles. Copper is the bottleneck. Valves and fasteners are in short supply. Heavy transformers are in worse shape. More copper will be shoved from light transformers to the heavy. Substitution of cast aluminum for copper in fractional hp motors has relieved the situation somewhat. Copper clad aluminum wire is being shipped from Germany as an added help. One firm distributing it in this country is receiving 200,000 pounds a month. An American firm is manufacturing it in lesser quantities. This material is used for conducting large amounts of current behind switchboards.

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MEYER FURNACE PROVES Speed Nuts®

✓ step up production ✓ cut reject rate
✓ simplify dealer installation

Those are three mighty important advantages to any manufacturer — especially today. The Meyer Furnace Company, Peoria, Illinois, did it by using only 24 SPEED NUTS on their Oil-Fired B Series Furnace. *Reports reveal a savings of 15 minutes assembly time per unit and a 25% reduction in the reject rate.*

The third advantage is highly important to a furnace manufacturer. Anything he can do to make the dealer's installation job easier and quicker means a tremendous premium in improved dealer relations. Meyer accomplished this by changing from fixed, welded bolts to SPEED GRIPS* for attaching the pressure oil burner. This change in installation *eliminated dealer complaints on time wasted due to misalignment of bolts and burner flange.*

This is a good time to look for little ways to save big dollars. And you're sure of specialized help—supplied by your Tinnerman representative. Call in this "fastener expert". Write for your copy of "Savings Stories" case histories. TINNERMAN PRODUCTS, INC., Dept. 12, Box 6688, Cleveland 1, Ohio. *In Canada:* Dominion Fasteners Ltd., Hamilton. *In Great Britain:* Simmonds Aerocessories, Ltd., Treforest, Wales. *In France:* Aerocessoires Simmonds, S.A.—7 rue Henri Barbusse, Levallois (Seine) France.

Detail sketch shows location of 4 bolts retained by 4 SPEED GRIPS. Flange of oil burner placed over SPEED GRIPS. Bolts through flange are easily aligned due to "float" provided by SPEED GRIPS. No need to bend bolts and damage threads. Burner is easily installed, easily serviced.
TINNERMAN Speed Nuts

Colleges and Political Domination

IN STEP WITH ALL OTHER INFLATIONS, the cost of operating colleges and universities has been steadily increasing. On account of higher and higher personal income taxes, college income contributed by private individuals is on the decline. Returns from endowments are decreasing. More and more of the cost of operating a college or a university must come from tuition fees.

Tuition is only one portion of the cost of a college education. The student must have food, shelter and clothing. He also must buy books. All of these costs have increased. Today it costs approximately twelve hundred dollars per year minimum for a man to go to an engineering college. Many cannot afford it. That has always been true. What is the answer?

Although the annual cost of a college education is almost three times what it was thirty-five years ago, salaries and earnings have also increased in about the same ratio. Hence the average man today earns more money that might be used to educate his children. However on account of the ever increasing taxes the "take home" pay is considerably less, perhaps even less than a decade ago.

The whole situation has been created largely by the tremendous expansion in federal spending and the cost of socialistic government programs. The "government boys" offer a solution. In President Truman's budget transmitted to Congress there is included a "rather insignificant fifty million dollar item" which is slated to be used to send possibly thirty thousand or more students to college at government expense. The program would be administered by the Office of Education which would presumably spend the usual twenty or thirty percent in administrating the thirty million dollar fund leaving twenty-one to twenty-five million dollars for scholarships. That would not be enough to send 25,000 to college.

The proponents of this program stress the great need for more college graduates. Obviously this carefully studied plan will further extend the powers of the federal government in controlling education.

It is axiomatic that sooner or later this wonderful sounding scholarship program would get tainted with scandals comparable to mink coats, R.F.C. loans, tax collecting and other federal operations. It is also axiomatic that any such program would be extremely inefficient in its operation and its cost would be far in excess of a reasonable percentage of the amount of money distributed for scholarships.

Free scholarship programs should be conducted on a local level and not on a national scale where the administrators are far removed from the university, the student and the control of the tax payer. Thousands of students are now going through colleges on free scholarships and loans provided by universities, private endowments, states, and industry. The federal plan is merely to increase the numbers and thereby gives the "boys in Washington" a chance to be "indiscreet" with the funds and to build still greater political weapons.

A far more equitable, effective and efficient method of lightening the burden on parents giving their children a college education would be to make all expenditures for a college education tax exempt. In other words, in addition to the usual dependence exemption the tax payer could claim as an exemption all of the money spent on his child or ward for tuition, books, board and room and all other expenses incurred in giving his children a college education. Effectively, that would reduce the cost of a college education twenty-five percent or more.

A further step toward the solution of this problem would be greater support of our technical institutions by private industries through the medium of endowment grants, scholarships, donations of laboratory equipment and similar contributions. Federal support should be the last resort. It is a definite step toward dictatorship. At the best it is inefficient, costly and wasteful and almost invariably involves, sooner or later, graft and corruption, politically known as impropriety and indiscretion. The argument for it is specious.

G. F. Zodenholt

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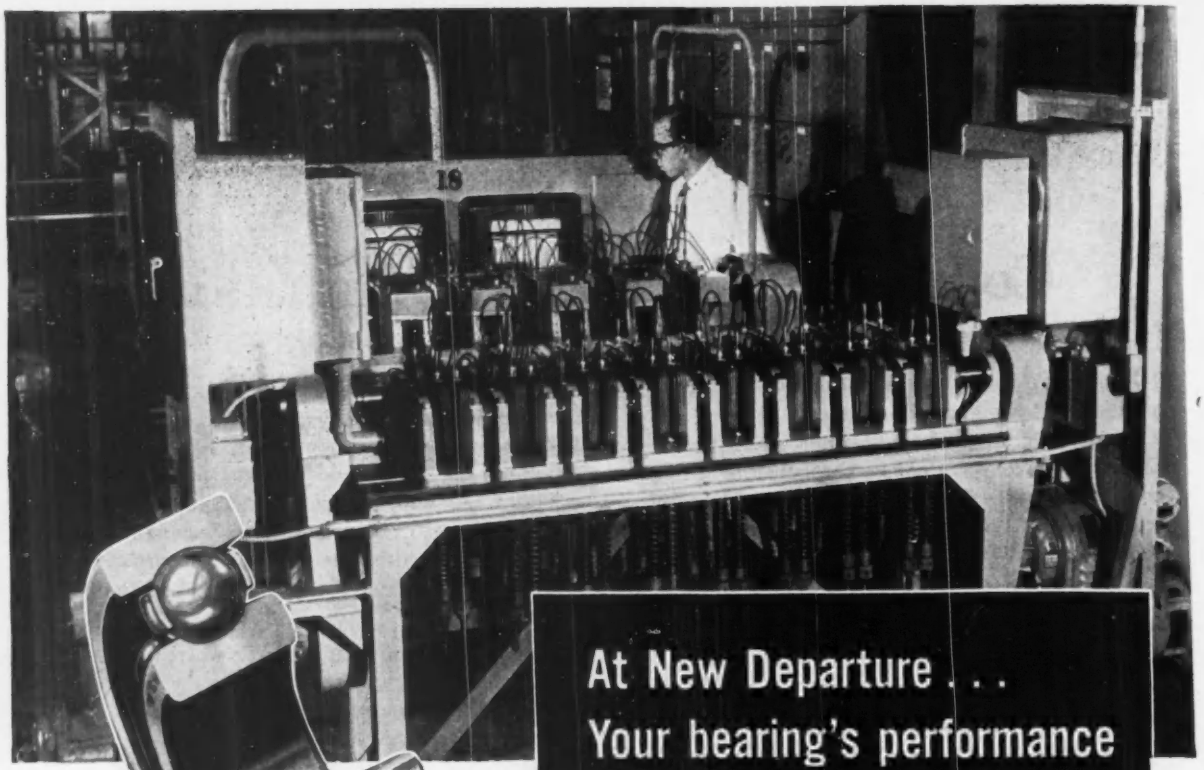

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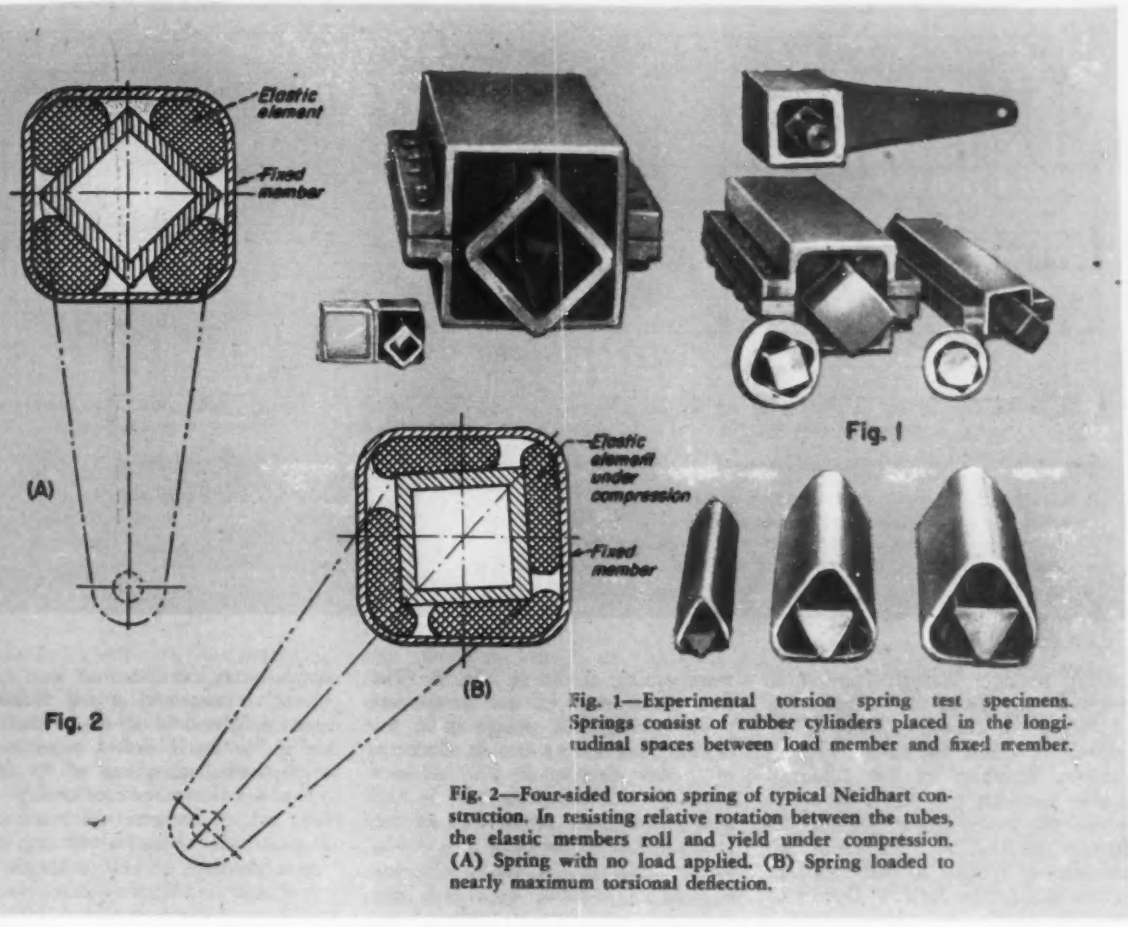

Fig. 2

Fig. 1

Fig. 1—Experimental torsion spring test specimens. Springs consist of rubber cylinders placed in the longitudinal spaces between load member and fixed member.

Fig. 2—Four-sided torsion spring of typical Neidhart construction. In resisting relative rotation between the tubes, the elastic members roll and yield under compression. (A) Spring with no load applied. (B) Spring loaded to nearly maximum torsional deflection.

ROBERT IREDELL
Product Development Manager,
Mechanical Goods Division,
The General Tire & Rubber Company

Elastic Rubber Cushion Springs

For Torque Load Applications

As THE RESULT of engineering research in the field of possible uses for rubber in industrial applications, a torsion spring has been developed that consists of an unusual combination of rubber and metal parts. Its simplicity of construction and uniform performance are qualities that are desirable in many applications.

The torsion spring, Fig. 1, consists basically of rubber parts in the form of cylinders that are contained within the spaces between concentric outer and inner shells or sleeves of polygonal cross-sections. A sectional view of a typical four-sided spring is shown in Fig. 2(A) with no load applied. The rubber rolls are assembled between the inner and outer tubes under slight radial compression and maintain the tubes in coaxial positions. No adhesive bond is present between the rubber parts and the tubes. Friction at the contact surfaces is the only resistance to slippage during deflection.

In resisting relative rotation between the outer and inner tubes, the elastic members roll and yield under compression. In Fig. 2(B) the four-sided spring is shown under its nearly maximum torsional deflection; the elastic elements are displaced from their unloaded positions and are in nearly pure compression.

As the spring is deflected, the rubber elements are compressed suffi-

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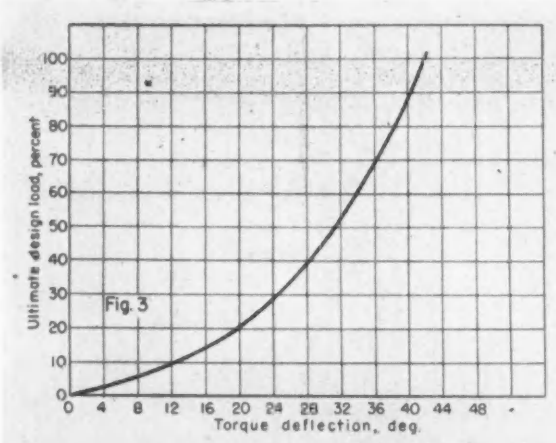

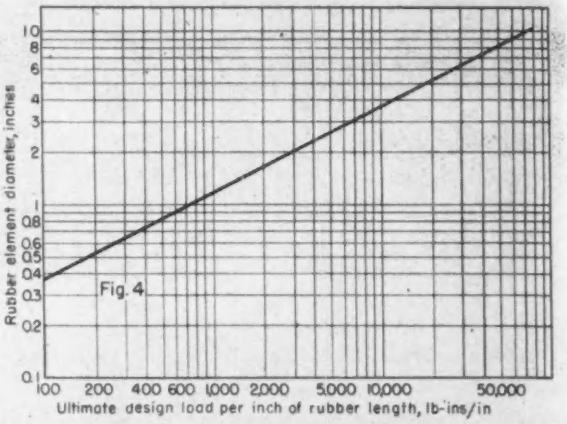

Fig. 3—Characteristic load-deflection curve of four-sided spring in which distance across flats of inner tube is twice the diameter of the rubber elements, and the distance across flats of the inside surface of outer tube is three times diameter of rubber elements.

Fig. 4—Relationship in four-sided spring between the rubber diameter size and the maximum torque load or load at a 42 deg deflection, per inch of rubber length.

ciently to offer enough increase in friction to prevent any slippage or chafing at the contact surfaces of the rubber parts and the tubes. The increasing resistance of the deformed rubber elements provides a spring in which the increments of angular deflection decrease with increasing increments of torque, so that snubbing occurs during the last few degrees of motion.

With load-deflection performance data available for a spring of a given design, the performance of other size springs of the same basic design can be plotted.

A basic design consists of a given size relationship among the component parts, a given compression modulus of the elastic compound, and polygonal members with a given number of sides. A load-deflection curve obtained from a specific basic design is characteristic of that for all springs the parts of which have the same dimensional proportions.

Test data obtained from springs of several basic designs and sizes show that the ultimate design load is a function of the square of the diameter of the rubber element. Thus a straight-line logarithmic curve can be plotted that relates the diameter of the rubber elements with ultimate load. A family of such curves for different basic designs contains all the information required to engineer the Neidhart torsion spring for practically any applicable problem.

In Figs. 3 and 4 are shown a set of curves for one basic design having a configuration like that of the four-sided spring shown in Fig. 2. The size relationship of the component parts in this basic design is in the design ratio 1:2:3; that is, diameter of rubber element is 1X; distance across flats of the inner tube is 2X; and the distance across flats of the inside surface of the outer tube is 3X. The material in the elastic elements is a high modulus, high flex, low compression-set type of crude rubber.

The characteristic load-deflection curve of this basic design is shown in Fig. 3, wherein load is plotted as a percent of maximum, which is determined by the geometry of the polygonal configuration. In this four-sided configuration, the maximum load, 100 percent, is measured at the ultimate design deflection of 42 deg. Actually, this spring could deflect more than the theoretical maximum of 45 deg. In Fig. 4 is shown the relationship between rubber diameter and maximum torsional load, or load at 42 deg. deflection per inch of rubber length.

A design consideration that should not be overlooked is that to obtain reasonable stability, the length of the rubber elements should be several times their diameter; a satisfactory minimum ratio being dependent upon the application. A minimum ratio of 3 to 1 can be used for couplings. For

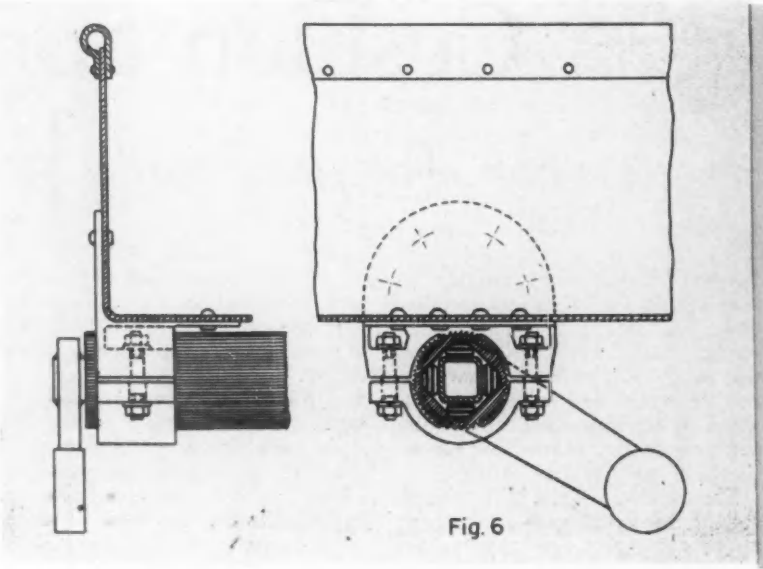

Fig. 6

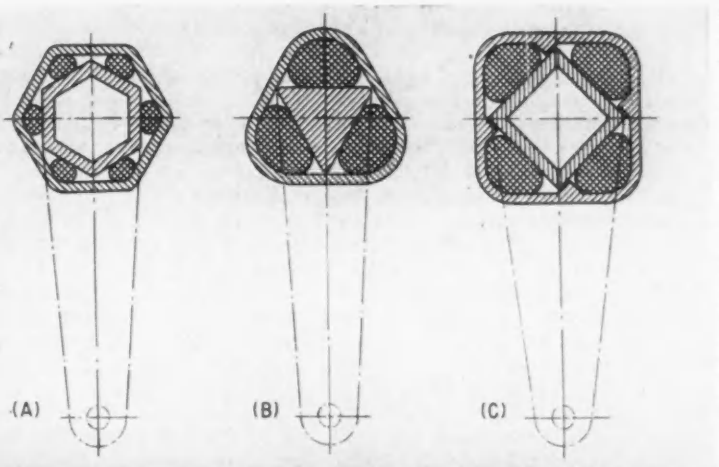

Fig. 5—Three basic designs of Neidhart elastic spring. (A) Hexagonal configuration. (B) Triangular configuration. (C) Four-sided configuration with safety stop. Design variations include reinforcing the elastic members, curving the contact surfaces, and using non-circular elastic members.

vehicular suspensions, ratios ranging from 8 to 10 to 1 are preferred. A sufficient length is needed to avoid "end effect" on the rubber in compression and to minimize conical deflections of the spring that result when the moment of the load is applied to only one end of the spring.

With complete sets of curves available covering all basic spring designs, the design engineer can readily choose the best combination of material and dimensional proportions for performance and economy.

EXAMPLE. Find the dimensions of a Neidhart spring having the basic design shown in Fig. 2, in which the design ratio is 1:2:3, and the rubber elements are made from compound No. 31460. The condition to be satisfied is that a deflection of 30 deg is desired at a torque load of 10,000 lb in.

SOLUTION. From Fig. 3 for this basic design, at a deflection of 30 deg the torque load is 45 percent of the ultimate design load. The ultimate design load, therefore, is

$$(10{,}000 \times 100)/45 = 22{,}222 \text{ lb in.}$$

The second step is to assume a definite rubber length that would be practical in whatever fixed space limitations exist. For this example, assume a rubber length of 30 in. could be used. Then for this length, the ultimate design load per inch of rubber length is

$$22{,}222 \div 30 = 740 \text{ lb in.}/\text{in.}$$

From Fig. 4 it is seen that for an ultimate design load per inch of 740 lb in., the diameter of the rubber elements should be 1 in. If this diameter results in a cross-sectional configuration that is unreasonably small, a larger diameter of rubber is found by selecting a shorter rubber length and then repeating the calculation for ultimate design load per inch of rubber length. If a rubber element of 1 in. dia results in a configuration that is unreasonably large, of course, a longer length of rubber is selected and the calculation repeated.

With continuing research and development of basic design and materials, the properties of these springs are subject to steady improvement.

Some of the modifications first studied covered the basic design factors and various polygonal sections, modulus range of the elastic member, and size relationship of the rubber element to the inner and outer members. Some of these modifications are shown in Figs. 5(A), (B), and (C). Other modifications include reinforcing the elastic members, making the surfaces of the rigid members in contact with the rubber curved instead of flat, and using other than round elastic members.

Captive designs similar to that of Fig. 5(C) have also been made in which the rigid members lock and prevent complete turning of the spring should fire or an unexpected

Fig. 6—Four-sided spring applied as a suspension for trailers up to two ton capacity. Light weight alloy extruded transverse tube is fixed by anchor boxes fastened to the chassis. Interior tube is of square section. Design is more expensive and refined than needed.

Fig. 7—Fixed member of torsion spring suspension on a ½ ton utility trailer is made of two flanged trough sections bolted together. This design is practical and inexpensive, it also simplifies assembly operations.

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overload destroy the rubber elements. Many additional modifications have been used to fulfill unusual requirements of particular applications of the spring.

The fields of application of the Neidhart spring are practically unlimited. Generally, it can be employed wherever a torsional spring would be practical. An important field is in the wheel suspensions of vehicles.

A design of a suspension for trailers up to two ton capacity is shown in Fig. 6. Each end of a transverse tube is fixed by an anchor box fastened to the chassis. The transverse tube is a light weight alloy extruded section with a fluted outer surface; the inside of this tube is square in section. An interior square tube is maintained coaxial with the outer tube by rubber rolls lodged in the angular spaces between the two tubes. The trailer wheels are mounted in axle arms joined to the interior tube. The caps of the anchor boxes, being attached with bolts, are detachable thus permitting a ready adjustment of the angular position of the outer tube in relation to the chassis as required by experience.

The fluted design for adjustment of angle shown in Fig. 6 is more expensive and refined than need be. For quantity production, an arrangement like that shown in Fig. 6 could first be used experimentally to determine the best working angle for the application and then manufacture the spring with that angle as a fixed angle. In Fig. 7 is shown a practical and inexpensive spring suspension for a $\frac{1}{2}$ ton utility trailer.

As a torsional cushion, the Neidhart spring can be incorporated in drive couplings and in the hubs of pulleys and sprockets to absorb the shock caused by sudden accelerations that occur in speed change and reversing, to compensate for slight maladjustments of alignment, and to obtain noiseless operation.

The flexible coupling shown in Fig. 8 (A) consists of two hexagonal hubs keyed to their respective shafts, two hexagonal tubes, twelve rubber rolls, a cylindrical casing having a hexagonal core, and two snap ring fasteners. This coupling is disconnected by removing one ring fastener and sliding the casing to one side. The coupling shown in Fig. 8 (B) is similar except that deep drawn flanged parts replace the hexagonal tubes and the casing.

Coupling elements are shown schematically in Fig. 9 assembled on a V-belt pulley, a flat belt pulley and a chain sprocket wheel. The mountings permit these transmission elements to align themselves axially.

Other torsional suspension applications include those for seats for tractors, trucks, and busses.

CONSTRUCTION AND MATERIALS. The polygonal members can be metal stampings, extrusions, castings, or forgings. Roughness of rubber contacting surfaces is not usually important, but a uniformity of surface condition is desirable. There should, however, be no sharp edges or burrs at contact areas that could cut or chafe the rubber. Reinforced plastic parts have been tried with success. When mass production is in prospect alumi-

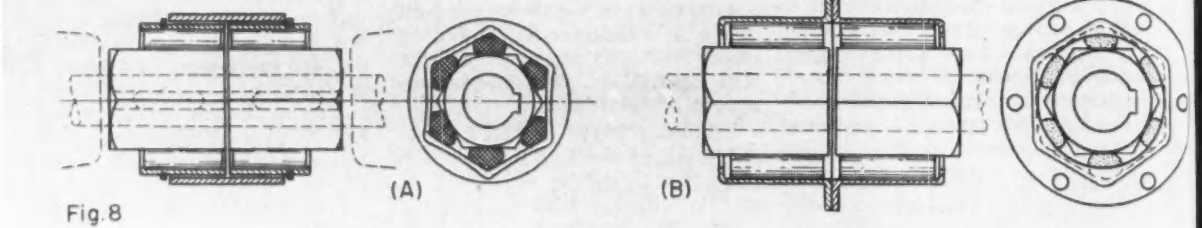


Fig. 8

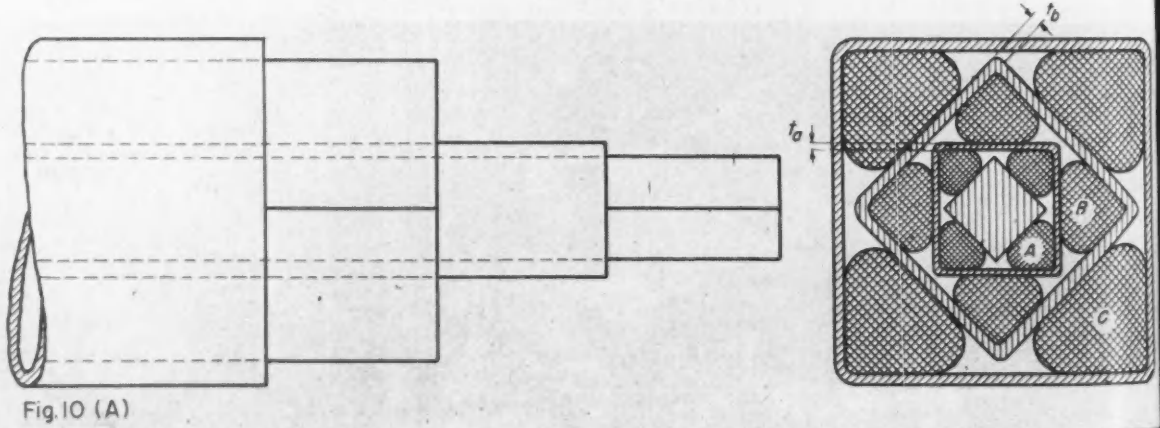


Fig. 10 (A)

Fig. 8—Hexagonal spring design applied in flexible couplings. (A) Coupling is disconnected by removing one snap ring fastener and sliding the casing to one side. (B) Another flexible coupling design, in this construction the outside tubes are deep drawn flanged parts.

Fig. 9—Elastic mountings absorb shocks from overloads and permit transmission elements to align themselves axially. (A) V-belt pulley. (B) Flat belt pulley. (C) Chain sprocket wheel.

ium extruded sections offer many advantages in design.

In many applications, the multi-sided parts are designed as integral parts of the mechanism or equipment.

The simple rubber elements can be easily manufactured by the rubber industry. The material specifications and control, however, require the experience of chemists and physicists versed in rubber technology. Complete laboratory facilities are also needed to analyze applications and to select materials that will perform effectively under given conditions.

ANGULAR DEFLECTION. The triangular configuration provides the largest angular deflection of a single unit. Based on geometry, this deflection is 60 deg each side of neutral, but the ultimate design limit is a few degrees less. It is possible, as shown in Fig. 10, to arrange springs either in series along the same axis or coaxially to provide practically any angular deflection required.

In the coaxial arrangement, Fig. 10 (A), the diameters in each spring are determined from the following formulas:

D_a = diameter of rubber elements in inner spring, in.
D_b = diameter of rubber elements in intermediate spring, in.
D_c = diameter of rubber elements in outer spring, in.
t_a = wall thickness of tube surrounding rubber elements of diameter D_a, in.
t_b = wall thickness of tube surrounding rubber elements of diameter D_b, in.

$$D_b = (3\ D_a + t_a)/2$$

$$D_c = \frac{3\ D_b + t_b}{2} = \frac{9\ D_a + 3\ t_a + 2\ t_b}{4}$$

The length of rubber for each spring is determined from a logarithmic curve similar to Fig. 4 to give the same total torque resistance for each spring, consequently the length of the outer spring will be shorter than that of the intermediate spring, and the length of the intermediate spring will be shorter than that of the inner spring.

DAMPING CHARACTERISTICS. In the working of the rubber elements, advantage is taken of the natural damping property or hysteresis of the compound. Only in applications requiring very low spring rates that are subject to high amplitudes is the addition of external damping means demanded, and even then the shock absorber problem is minimized by the natural damping characteristics of the Neidhart spring.

END CREEP. As a result of the substantial compression forces on the rubber along with the relatively large length-to-diameter ratio employed, there has been no evidence to date of the rubber rolls shifting or walking out axially during torsional flexing. With but rare exceptions, the use of thrust washers or bearings in an application would be a requirement not attributable solely to the Neidhart spring design.

EFFECT OF TEMPERATURE. Until recently natural rubber compounds were superior to synthetic compounds for operation in cold temperatures, but today synthetic compounds are available that operate satisfactorily at —70 F. For operating at high temperature natural rubbers are limited to 158 F; now synthetic compounds will operate at temperatures higher than 200 F. These are ambient temperature conditions; momentary peak temperatures at either extreme have little or no effect on the rubber parts.

CHEMICAL DETERIORATION. With the recent advances in the chemistry of rubber-like materials, it is safe to say that with few exceptions, satisfactory performance can be had in rubber applications without too much concern about chemical deterioration. Within limitations, which grow narrower each day, the failure of a rubber product because of the chemical reaction of oxygen, ozone, sunlight, oils and various substances can be placed on faulty choice of compound.

LIFE OF RUBBER PARTS. One common failure in rubber parts subjected to flexing in tension or shear is fatigue. This fatigue is evidenced by flex cracks within the rubber part. When rubber is precompressed, as in the Neidhart spring assembly, and is flexed in compression, flex cracks or fatigue do not occur.

Another type of failure, even in rubber parts under compression, is evidenced by chafing or "threading-out" of the rubber. This condition is caused by poor stress distribution of the precompression forces in the assembly of the rubber parts. The simplicity and ease of assembling the Neidhart spring precludes such difficulty. The increase of compression forces as the spring is worked is greater than the increase of the forces tending to cause slippage, therefore, chafing does not occur.

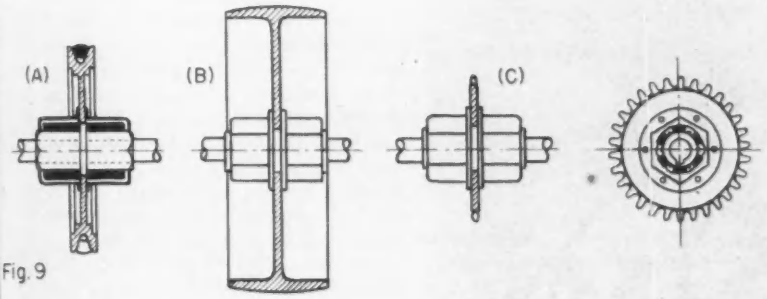
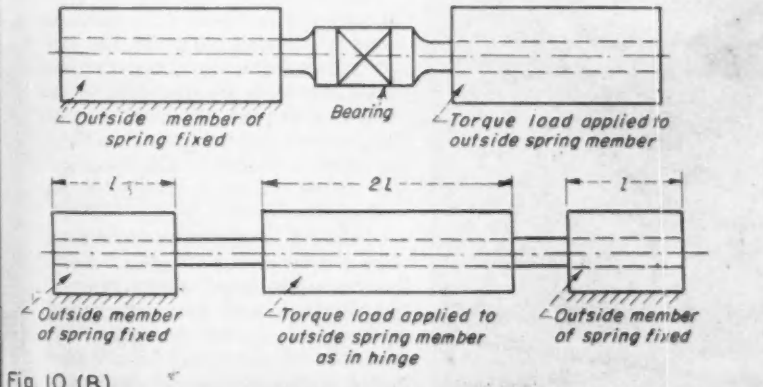


Fig. 9


Outside member of spring fixed
Bearing
Torque load applied to outside spring member
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2l
l
Outside member of spring fixed
Torque load applied to outside spring member as in hinge
Outside member of spring fixed
Fig. 10 (B)

Fig. 10—Multiple spring arrangements for obtaining large angular deflection. (A) Coaxial arrangement. Because of the limited space available the view shown here is of the right-hand end only of the spring, its left-hand end is symmetrical with the end shown. (B) Straight line series arrangement.

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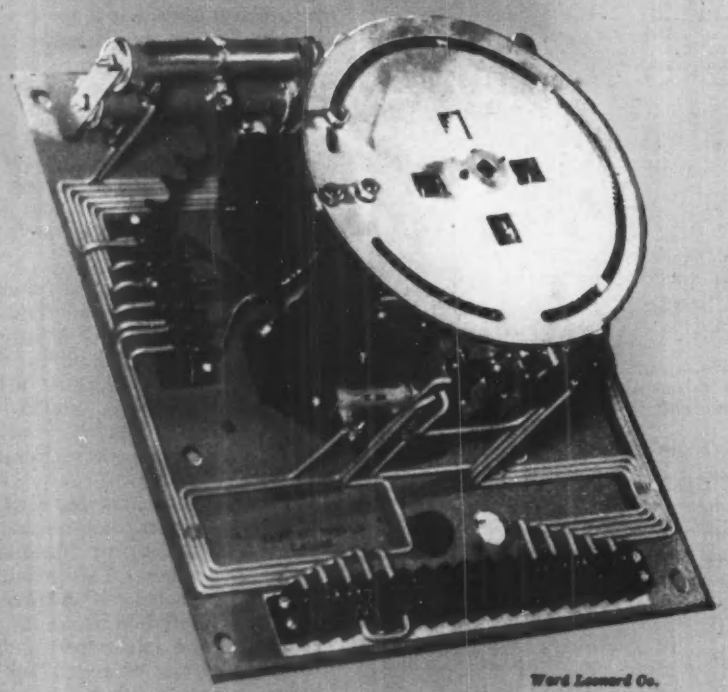
Current Trends in Fixed Resistors

PHILIP S. SCHMIDT
Stromberg-Carlson Company

While established types still dominate the field, many new resistors have appeared as the result of demands for higher operating temperatures, greater stability, closer tolerances and lower cost.



Ward Leonard Co.

Tubular power wire-wound resistors are widely used speed control. The adjustable rheostat pictured is motor driven.

UNTIL RECENTLY most civilian needs for resistors have been met by types developed a number of years ago. These needs, for the most part, were for:

1. Low wattage, low precision resistors.
2. Relatively high wattage, low precision resistors.
3. Low wattage, high precision resistors.

Requirements of the first class have been met mainly by carbon composition resistors; those of the second by power wire-wound resistors; and those of the third by accurate or high precision wire-wound units.

A number of new resistor types have appeared as a result of applications calling for wide temperature ranges (—65 C to 200 C), miniaturization and lower cost. The new applications and new conditions of use presently being encountered by resistors have served to point up the shortcomings of conventional types.

Composition Resistors

A composition resistor is made up of carbon with an organic binder. A common method of construction, Fig. 1, is to form a symmetrical pellet of this composition, bond leads to the ends of the pellet, and then mold a case, usually of a phenolic resin or Bakelite, around the assembly with the leads projecting. The case insulates the pellet and protects it from external hazards, such as high humidity. An alternate method of construction involves attaching the leads to the pellet, slipping the pellet-lead assembly through a ceramic tube, then sealing the ends of the tube with cement.

The method of attaching the leads to the pellet is important, as the leads serve to dissipate some of the heat generated in the resistance element. Often, the leads are embedded in the resistance element. In some cases, an enlargement in the shape of a nailhead is formed on the lead. The upper surface of the nailhead is attached to the end of the pellet.

A third type of composition resistor uses a tube of special glass. Leads having an enlarged portion are inserted into the tube with the enlarged portion flush against the ends of the tube. The resistance material is bonded to the outside of the glass in a thin layer with a fillet built up around the enlarged portion in order to make contact.

Axial leads have virtually superseded the earlier radial type, at least for sizes of one watt and under. Some radial-lead types are still recognized

by military specifications in sizes up to 5 watts. Composition resistors, being small and light, are usually supported by their leads.

Standard resistance values for composition types range from 10 ohms to 22 megohms in wattage ratings from ¼ to 2 watts, with some manufacturers producing models having up to 5-watt ratings. The nominal value of resistance is usually indicated in the case of composition resistors by a color-coding scheme in which the first color indicates the first significant figure of the value; the second color, the second significant figure; and the third color, the number of zeros following the second significant figure. Table I indicates the placement and meaning of each color. Insulated resistors may have any body color except black, the latter being reserved for uninsulated types. The manufacturing tolerances of composition resistors may also be indicated by color, as shown in the table.

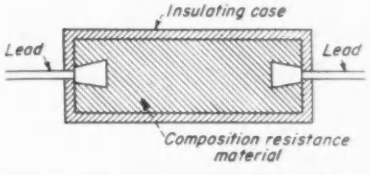


Fig. 1—Composition resistor is made up of carbon with organic binder. Note headed ends of leads for attachment.

The voltage rating of composition resistors is defined at low voltages by the relationship

$$E = \sqrt{PR}$$

where E is the voltage rating in terms of d-c or rms values, as the case may be; P is the rated power in watts; and R the nominal resistance in ohms. At high voltages, the dielectric constant of the resistance element and the voltage gradient are the determining factors in performance.

The relative instability of composition resistors under heat makes soldering a problem, since installation in a circuit may alter the value of resistance markedly. The applicable military specification holds the permissible resistance change after soldering to 3 percent or less. On momentary overloads, resistors for the military must withstand 2.5 times rated voltage for 5 sec with less than 5 percent change in the resistance value.

Temperature coefficient of resistance is generally stated as the percent change in resistance per degree C, relative to the value at 25 C. The voltage coefficient of resistance is the percentage change in resistance with an increase of one volt in the applied potential. The voltage coefficient of composition resistors is relatively small, being limited to only 0.035 percent.

Composition resistors have definite limitations as the ambient temperature is raised. It is customary to derate such resistors for use in high ambients. The derating curve, Fig. 2, is that given by Joint Army-Navy specification JAN-R-11, covering Resistors, Fixed Composition.

The Power Wire-wound Type

Where appreciable amounts of power must be dissipated, the circuit designer must rely on power wire-wound types. As pictured in Fig. 3(a), these generally comprise a central tube or core of ceramic or other insulating material, a winding of resistance wire, a set of terminals fastened to the core and a coating of insulating material to keep the wire in place and to protect it against shorted turns, corrosion and abrasion. The coating also serves to hold the terminals firmly in place.

An exception to the conventional type of construction incorporates wire upon which an inert coating is sintered before winding, Fig. 3(b). Even further protection is afforded by placing the core and winding inside a ceramic or a glass tube and hermetically sealing the ends.

Resistance wire for power wire-wound resistors is generally an alloy of nickel with chromium or copper, the specific resistivity ranging from 30 ohms per circular mil-foot at 20 C for number 30 alloy (2% Ni—98% Cu) up to 800 ohms per circular mil-foot for nickel chromium in the proportion 75:20. The coefficient of expansion of the wire used for power resistors may be critical, since too great an expansion may crack the protective outer coating.

The coating employed for power wire-wound resistors is a vitreous or an organic enamel. In manufacture, the former is brought to red heat after coating, whereupon it fuses into a hard, smooth coat. The coating is a good conductor for heat, but insulates the winding electrically.

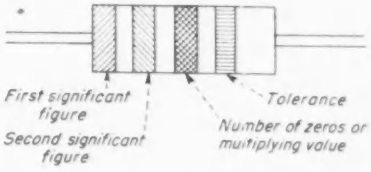
Power wire-wound resistors are made in ratings between 5 and 200 watts in values as low as 0.05 ohms and as high as 1.7 megohms. The standard tolerance of power wire-wound resistances is usually ±10%, but even ±1% may be had on special order, as may non-stock values of resistance.

Resistance values of wire-wound types are limited by the minimum size of wire and the maximum length of tube it is feasible to employ. Values intermediate to stock values can be obtained by specifying an adjustable resistor, Fig. 3(c). This is similar to the fixed type, but a portion of each turn is exposed and an adjustable band is provided. The clamp may be tightened at any desired position along the tube to make contact with an exposed turn of wire.

Adjustable resistors are useful as voltage dividers, but the possibility of damage through repeated tightening of the clamp on the resistance wire has prevented their acceptance by the military. Where greater ease of adjustment is necessary, the arc-type adjustable resistor, Fig. (3)d, is useful. It is made in resistances from one to 2,000 ohms, and has a rating of one watt. Where a resistance tap is required but adjustment is not, resistors with taps in prearranged positions can be used.

While the smallest of power wire-wound resistors can be supported by their terminals, the weight of most power-type resistors makes bracket mounting necessary. The brackets are insulated from the winding or, where the resistor is to be mounted on an insulated panel, form part of the terminal. The type of resistor shown in Fig. 3(a) may be mounted by a metallic strap around the outer ceramic housing. The terminals themselves are either lug, pig-tail or ferrule type (the latter designed to fit standard fuse clips), or may even have the Edison screw base standard on incandescent lamps. However, in the smaller ratings of power wire-wound resistors, such as the 5 and 10 watt units pictured in Fig. 3(e), axial

Table I—Resistor Color Codes



Color	Significant Figure	Multiplying Value
Black	0	1
Brown	1	10
Red	2	10^2
Orange	3	10^3
Yellow	4	10^4
Green	5	10^5
Blue	6	10^6
Violet	7	10^7
Gray	8	10^8
White	9	10^9
Gold	± 5% tolerance	10^{-1}
Silver	+10% tolerance	10^{-2}
No color	+20% tolerance	

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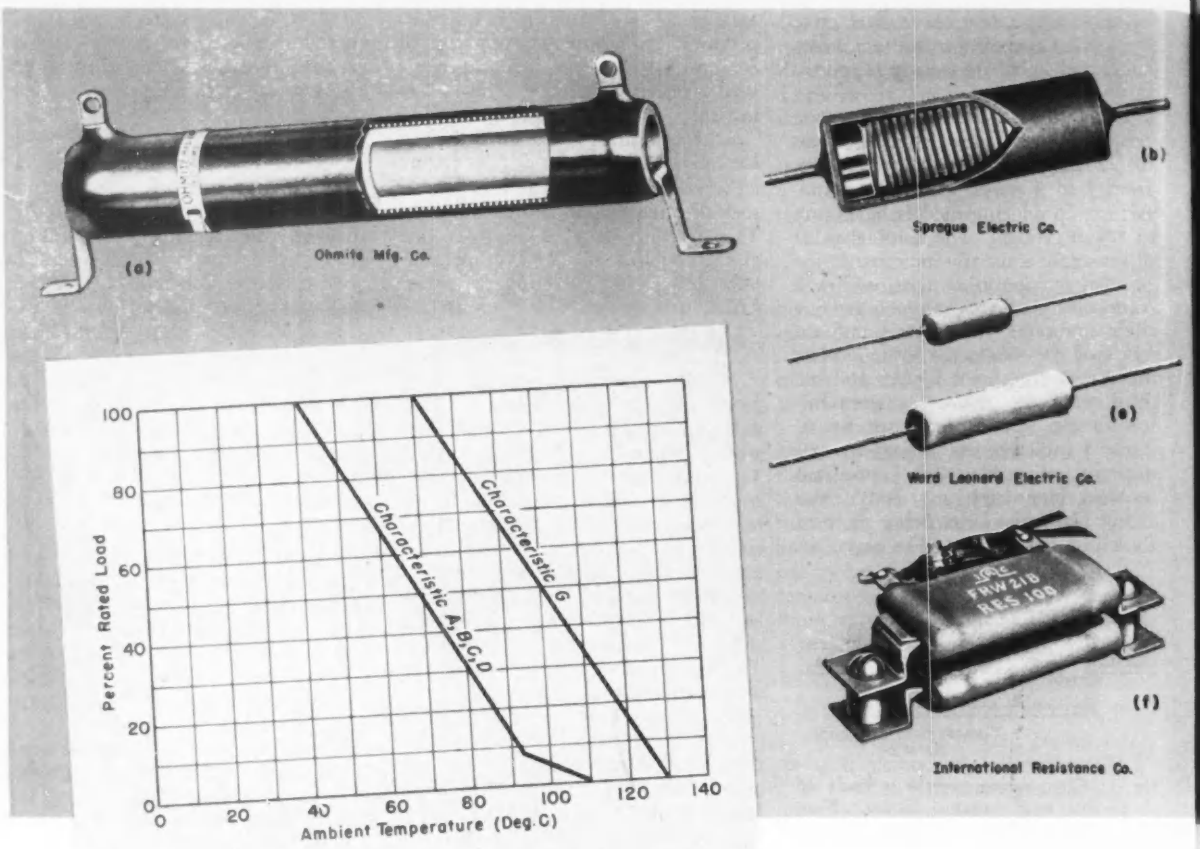

Fig. 2 — Derating curves for fixed composition resistors indicate percentage of nominal wattage that can be applied safely to a resistor at temperatures other than 40C. Characteristic designations apply to various resistor types covered in specification JAN-R-11.

leads are now being manufactured. These have the advantage of simplified installation, requiring no mounting brackets or panel drilling.

Power wire-wound resistors are sometimes mounted vertically on a panel or chassis with a bolt extending through the center hole in the form. In this case, resilient washers are included at both ends of the form to absorb shock. Care is taken in mounting power wire-wound resistors to provide full protection against voltage breakdown between terminals, or from terminals to mounting bracket.

The allowable power dissipation of wire-wound resistors in free air is determined by the materials of which they are made. The insulating coating employed is sometimes a weak link, although a number of coatings are available which will withstand the NEMA and Underwriters' Laboratories ratings of 300 C temperature rise. Other coatings, designed for maximum protection against fungus, high humidity, or salt air, are limited to lower working temperatures. In many cases, the allowable working temperature may be limited not by the resistor itself, but by the temperature characteristics or insulation of nearby components.

The winding tubes employed for power resistors are not always round, but may be relatively flat in cross section. This is an advantage because resistors wound on such forms offer a high power-space ratio and may be stacked compactly, Fig. 3(f). However, good ventilation must be provided between the individual resistors of a group.

Another flat power resistor, Fig. 3(g), is designed to be mounted against the chassis. A metal outside casing transfers heat from the interior of the resistor to the chassis for radiation. The insulating material is a mica-filled phenolic compound. Whereas other types of power resistors are rated in watts of dissipation in "free space" (no object closer than 12 in. except for mounting clips, which may be not closer than 2 in. below the resistor), this type is rated when mounted on a 10 in. square steel plate ½ in. above a wood table top. The resistor is designed for operation at 100 C above a 40 C ambient.

Free space is seldom encountered in practice, so a derating factor must be applied for most applications. The value of this factor depends on the application and is determined from experience rather than tabulated data. As a general principle, power wire-wound resistors are better mounted horizontally than vertically to benefit most from rising air curents.

Since wire-wound resistors are essentially coils of wire, they have appreciable amounts of inductance and some stray capacitance. To improve the a-c performance of any wire-wound resistor, a non-inductive winding, such as the Ayrton-Perry, can be used. The Ayrton-Perry is a helical winding having spaced-apart turns, with another winding in the opposite direction being laid between those turns. But the Ayrton-Perry windings obtain their improved reactive effects at the expense of lowered maximum resistance for a given resistor size. A sec-

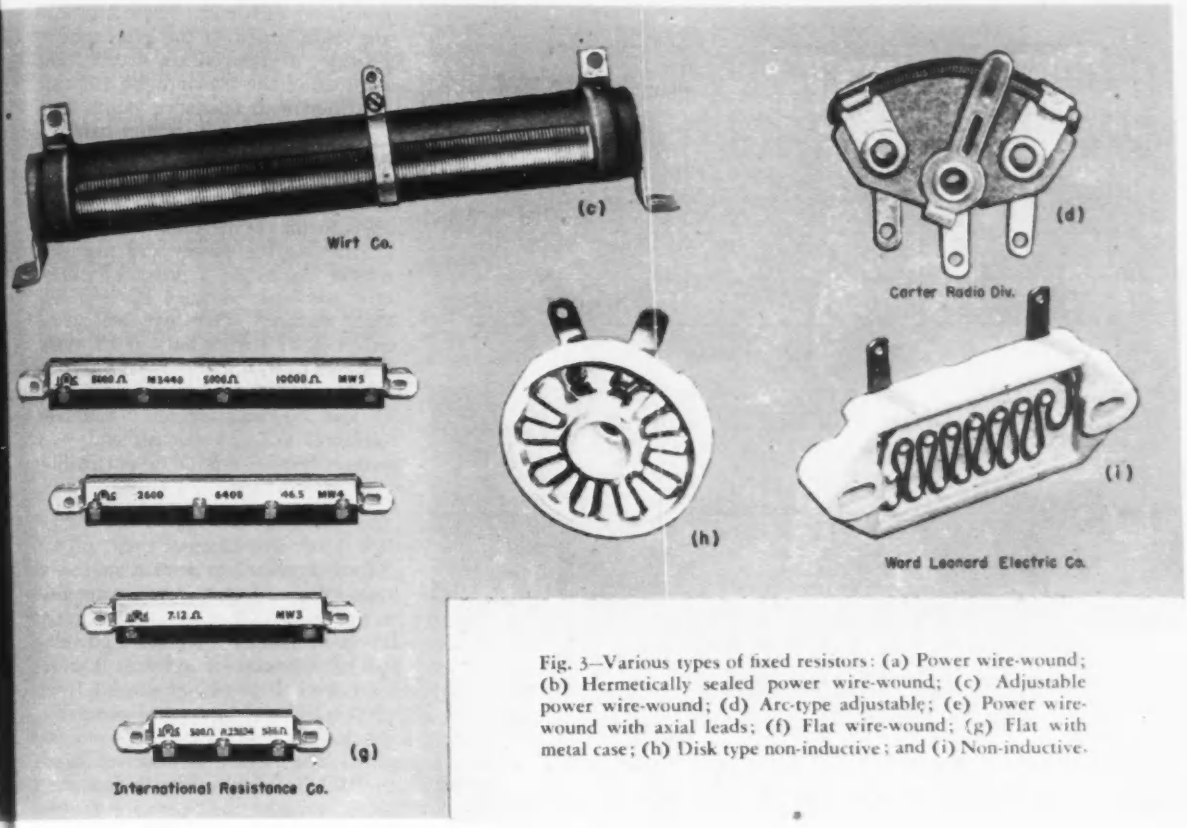

Fig. 3—Various types of fixed resistors: (a) Power wire-wound; (b) Hermetically sealed power wire-wound; (c) Adjustable power wire-wound; (d) Arc-type adjustable; (e) Power wire-wound with axial leads; (f) Flat wire-wound; (g) Flat with metal case; (h) Disk type non-inductive; and (i) Non-inductive.

ond type of non-inductive resistor, Figs. 3(h) and 3(i), employs a flat ceramic plaque having grooves or recesses to receive the wire. The wire is not wound around the core but is laid back and forth in the grooves on the flat surface of the plaque. The flux linkages set up by each segment of the zigzag winding tend to cancel those set up by the adjacent segment, so that the total inductance is less. Also, because there is only a small potential difference between segments while the distance separating them is comparatively large, capacitance effects are reduced.

In addition to the larger types, wire-wound resistors of the non-precision class are supplied in small ratings ($\frac{1}{3}$ to 2 watts) in molded housings, similar to those used for composition resistors. Such types are useful where low noise, low resistance value, or other special characteristics not available in composition resistor lines are required. The resistance values available range from 0.24 ohms to 8,200 ohms, with tolerances from ± 5 to ± 20 percent.

Accurate Resistors

Close resistance tolerances are achieved in the acurate, or precision, wire-wound class of resistors by winding enameled resistance wire on a spool or bobbin. This spool is usually ceramic, but may be plastic if weight is a factor. A bolt passing through a hole in the center of the spool is used to mount the resistor against the chassis.

Terminals of precision resistors are formed from pig-tail leads wound around the body of the spool near the ends or, sometimes terminal caps are cast of white metal around the ends. Terminals are supplied in pig-tail or lug form, projecting radially or axially.

The resistance capabilities of accurate wire-wound resistors are determined principally by the characteristics of the wire. The maximum resistance is limited by the minimum wire gage permissible for a given application and by the amount of wire that can be held on the spool. The minimum wire size is determined by the mechanical strength required. The applicable military specification limits the minimum wire size to 0.0015 in. in diameter, but some manufacturers are prepared to wind wire only 0.0007 in. in diameter. It is customary to relieve the strains set up in the winding process by aging the resistor for a time at high temperature to insure long-term stability.

Wire drawn from an alloy of manganese with copper, manganin, is commonly used for low values of resistance. For higher values, Evanohm, a special alloy of nickel and chromium with aluminum and iron is finding increasing favor. In Fig. 4 is given a comparison of the temperature coefficients of this alloy and manganin.

Nominal resistance values for precision types range from 0.1 ohms to 5 megohms, the latter value being obtained from a unit measuring only 2-$\frac{1}{32}$ in. long by $\frac{7}{8}$ in. in diameter. Precision resistors are now available without a center hole and with axial leads, thereby increasing the useful winding space. In this construction, resistance of 200,000 ohms can be placed on a spool $\frac{3}{8}$ in. long and $\frac{5}{16}$ in. in diameter. Tolerances available in the precision classification range from ± 3 percent for the semi-precision 20 watt model down to ± 0.05 percent for commercial grades and to ± 0.02 percent for laboratory types.

To minimize inductance effects it is common practice to wind the wire in "pies", or multiple side-by-side sections, with winding directions alternating from section to section. This

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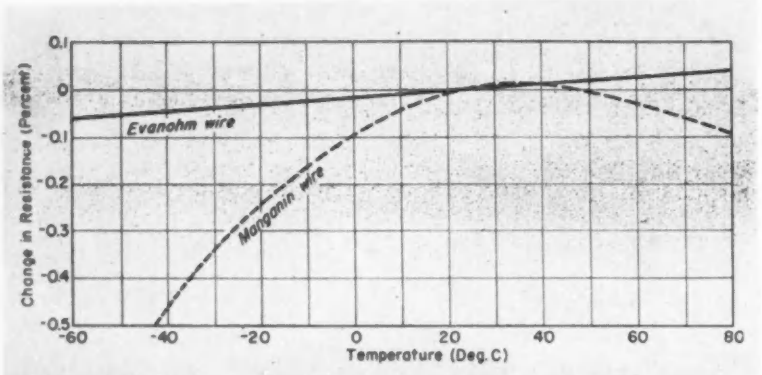

Fig. 4—Comparison of temperature coefficients of Evan-ohm and manganine alloys used for resistance wire. Both are used in accurate types.

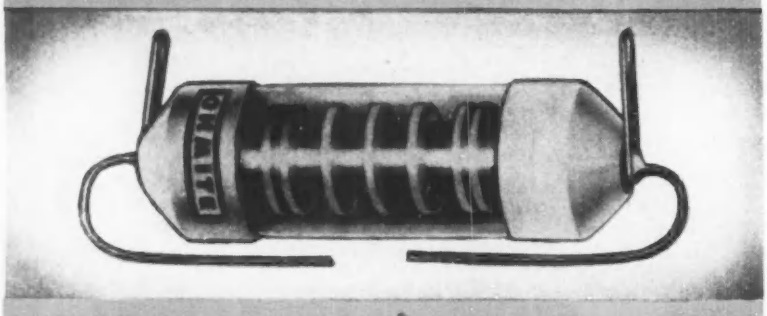

Fig. 5—Glass encased precision wire-wound resistor. Such tightly sealed resistors are relatively impervious to moisture and fungus attacks.

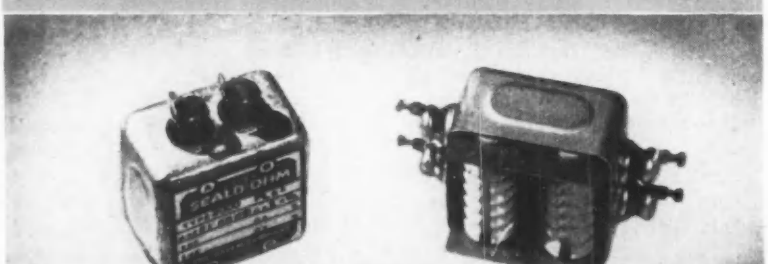

Fig. 6—Hermetically sealed metal case offers protection to this type of precision wire-wound resistor. Many military applications require sealed units, which are becoming available in increasing numbers and models.

winding method produces satisfactory results up to 50 kc/sec. Also available is the non-inductive bifilar winding in which two wires are wound side-by-side on the form and are connected in series. Some laboratory types employ a wire-weaving technique to improve the a-c performance.

For maximum protection, precision resistors may be hermetically sealed in glass or metal cases, as shown in Figs. 5 and 6 respectively. Ordinary varnished resistors may be obtained with special fungus-resistant coatings. Still another type of precision resistor uses a coating of vitreous enamel fired over a single-layer winding.

Certain styles of precision resistors are useful as voltmeter multipliers. Such resistors comprise a number of pieces of wire encased in a glass cylinder with metallic ferrule-type terminals on each end. These terminals are solder-sealed to the glass tube to provide a hermetically-sealed unit. Resistors of this classification are manufactured with resistance values from 0.5 to 6 megohms, in ratings based on an allowable maximum current of one milli-ampere for all sizes. The maximum voltage which may be applied is one kilovolt per megohm of resistance.

Stradling the power and precision resistor classes are a group of miniature precision resistors of relatively high wattage. One size measuring only 1-$\frac{1}{16}$ by $\frac{1}{2}$ in. is rated at 25 watts. Resistors of this pattern are made from one ohm to 12,000 ohms in 2, 5, 10, 25 and 50 watt ratings. Standard tolerances are $\pm$ 1 percent and $\pm$ 3 percent, but $\pm$ 0.05% is obtainable.

Special Types

Some applications involve unusually high voltage or frequency, or require an unusually high value of resistance. Especially manufactured for high voltages is a group of resistors having maximum voltage ratings ranging from 3,500 volts to 125 kv, with acompanying wattage ratings from one to 90 watts. The 125 kv, 90 watt size measures 18.5 in. long by 2 in. in diameter, and is available in resistance ranges from 7.5 to 100,000 megohms. The maximum resistance rating available in this pattern is 10^6 megohms. In general, this type of resistor comprises a carbon coating applied helically around a steatite rod, with a protective coating of varnish over the exterior. Physically large standard resistors, such as those for high wattage ratings and high values of resistance, show the most rapid drop-off of resistance with frequency. One tiny $\frac{1}{4}$-watt resistor, for example, retains 98 percent of its d-c resistance value up to 30 mc/s for values from 30 ohms to 10,000 ohms, while a 90-watt, 10,000-ohm unit retains only 62 percent of its d-c value at 10 mc/s, a frequency only one-third as high. But now available for high frequency uses are specially designed resistors that exhibit a wide variety of frequency characteristics. Although most types of resistors exhibit a loss of resistance as the frequency rises, in some cases the resistance value actually increases.

In the ultra-high resistance class, resistors are available in values to 5 x 10^{13} ohms. This size measures 3 in. long and is rated at 15 kv maximum. As with the high voltage and high frequency types, such resistors usually comprise a carbon coating on a ceramic rod. One such unit, is offered in resistances ranging from less than a megohm to more than 10^{14}

ohms. This resistor is sealed in a glass envelope that is dipped in silicone varnish for maximum stability.

Of unusual interest are the characteristics available in a group of resistors having conductive ceramic bodies. These characteristics include high negative voltage coefficients; voltage coefficients equal to those of copper and aluminum conductors; and the ability to operate with body temperatures as high as 300 C. Still other groups of special resistors show large variations with temperature or with applied voltage, making them useful respectively as pyrometer elements and lighting protectors.

Other New Developments

The need for a unit providing a compromise between the accuracy and stability of precision types and the wide resistance range and small size of composition resistors is being met by the new technique of depositing a thin film of resistance material on an appropriate form. The film may be made of carbon or a metal.

Deposited carbon resistors are made by the pyrolytic or cracked carbon process. This involves placing a ceramic form such as a rod or tube, in a furnace. A hydrocarbon gas is introduced into the furnace and decomposed at a temperature of about 1000 C. Carbon is deposited in a thin crystalline film on the form as a result of this decomposition, or pyrolysis. The thickness of the film can be controlled by varying the length of exposure, the percentage of carbon used in the gas and the temperature. Thereby, a full range of resistance values can be obtained. The deposited film is only about 10^{-8} in. thick, but is harder than carborundum and highly resistant to abrasion.

After deposition of the carbon, the rod is helically grooved to lengthen the path of the resistance element and to allow the final resistance value to be adjusted. Resistance values up to 100 megohms can be obtained as compared to the 22-megohm upper limit of small composition resistors. Grooving tends to increase the residual inductance of the unit, however.

Deposited carbon resistors compare favorably in size with composition resistors. A one-watt unit of one make, for example, measures $\frac{5}{16}$ in. long by $\frac{9}{32}$ in. diameter, while a typical 1-watt composition design measures $\frac{3}{4}$ by 0.280 inch.

In price, as in physical behavior, the deposited carbon resistors are intermediate to the wire-wound and composition types. The major production of deposited carbon resistors to date has been in sizes of two watts and less, although it is to be noted that the film employed is thin and is therefore well cooled. The standard tolerance is ± 2 percent, with ± 1 percent and ± 0.5 percent available on special order. Also offered are ultra-high-resistance types having values as high as 100,000 megohms, although in this case tolerances are generally ± 10 percent or more.

Carbon film resistors are distinguished not only for their improved accuracy compared to that of composition resistors, but also for their greater stability, lower noise level, better high-frequency performance, and improved temperature and voltage coefficients. Skin effect—the increase in effective resistance caused by the tendency of high frequency currents to "crowd" near the surface of a conductor—is virtually absent from cracked carbon resistors because the resistance element is literally all skin. The temperature coefficient of resistance of cracked carbon types is always negative.

A recent improvement in deposited carbon resistors is the addition of boron to the gases to be pyrolyzed. Markedly lower temperature coefficients of resistance result, being about the same order of magnitude as encountered in wirewound types. The inclusion of boron in these "borocarbon" resistors increases the specific resistance, and makes possible resistivities of more than 1,000 megohms per cubic centimeter. These resistors show small effects from aging, thus have improved stability. Borocarbon resistors are offered in ratings from $\frac{1}{4}$ to two watts and maximum resistances from 5 to 5,000 megohms.

Another high-stability development is the metal film resistor, produced by a process using both pyrolysis and chemical action to deposit a thin film of metal on a ceramic tube. The tube is hollow for improved cooling. The film is sealed by a vitreous enamel and a special synthetic coating. The resistance material is grooved to provide a longer path.

The specific resistivity of metal film resistors is proportional to the thickness of the skin. This contrasts with deposited carbon resistors, whose specific resistivity is independent of film thickness. Metal film resistors are available in values from $\frac{1}{2}$ ohm to 30 megohms in ± 1 percent and ± 5 percent tolerance classes. Power ratings range from $\frac{1}{2}$ to 5 watts. The 1-watt size measures one in. long by 0.370 in. in diameter.

A new kind of resistor, the printed resistor, meets the need for a cheap and compact unit. Usually, accuracy and power-handling ability are sacrificed in order to achieve these aims.

Printed resistor developments fall into two broad classifications. In the first, the resistors are produced directly on a base plate by a printing, etching or other technique. The base plate serves as a chassis for the other circuit elements—coils, capacitors, connectors—which are produced by stamping or by a printing process. In some cases, the entire printed circuit, including tubes is encased in an insulating material with only the leads projecting.

The printed resistor is also manufactured as a separate component, on a small base plate, which can be incorporated in standard or printed circuits.

One type of resistor is printed on a tab of mica or other insulating material less than 0.01 in. thick. The tab measures 0.25 in. long by 0.062 in. wide. Each end of the tab is silvered on the printed side, and when one of the units is to be installed in the circuit, the ends are coated with silver paste and the resistor is set in the desired position. The paste is then allowed to dry.

These resistors operate at 200 C with little change in value. Power ratings are in the fractional-watt range, being dependent to a considerable extent on the type of base material used. Base materials range from kraft paper through mica and glass to teflon, depending upon the cost-performance compromise desired. Resistors printed directly on these materials may be had from 1 ohm to 1,000 megohms, in tolerances of ± 20 percent.

The latest technique reported by the National Bureau of Standards involves placing the resistance material, a carbon and silicone resin compound, on adhesive tape. The resistor is installed by pressing the tape into place in gaps left in the circuit wiring. As with composition resistors, all of these tape resistors have the same dimensions, individual values being obtained by varying the proportions of the mixture.

The resistance material is sprayed onto the asbestos paper tape in multiple coats. After drying, the resistance material is protected with a thin layer of polyethylene tape. Final dimensions of each unit are 0.5 in. long by 0.13 in. wide. Values experimentally produced range from 100 ohms to 10 megohms. They must be cured at 300 C for four hours and at 200 C for 24 hr after installation on the printed circuit plate. However, the method offers good control of resistance value and provides a number of characteristics similar to those of deposited carbon resistors.

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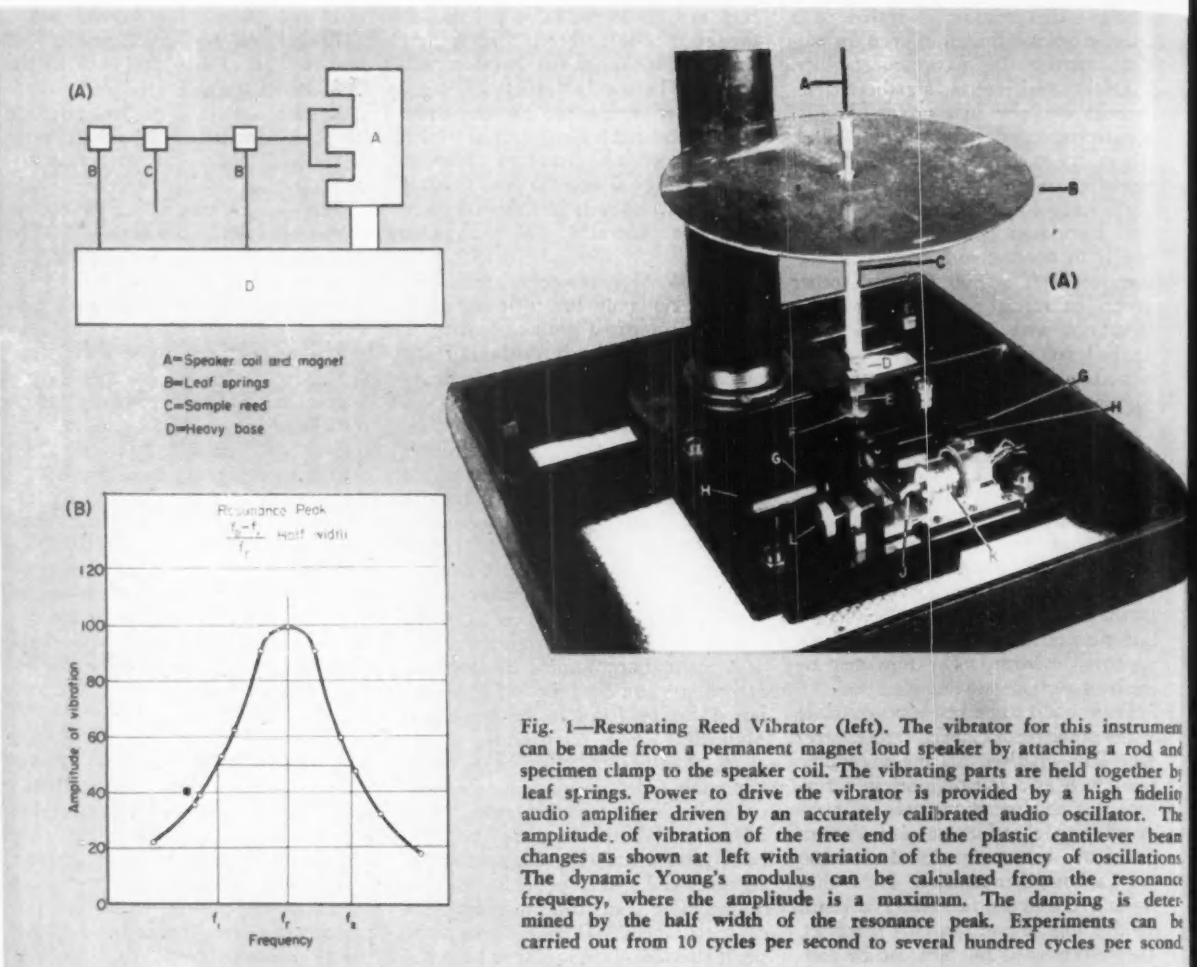

Fig. 1—Resonating Reed Vibrator (left). The vibrator for this instrument can be made from a permanent magnet loud speaker by attaching a rod and specimen clamp to the speaker coil. The vibrating parts are held together by leaf springs. Power to drive the vibrator is provided by a high fidelity audio amplifier driven by an accurately calibrated audio oscillator. The amplitude of vibration of the free end of the plastic cantilever beam changes as shown at left with variation of the frequency of oscillations. The dynamic Young's modulus can be calculated from the resonance frequency, where the amplitude is a maximum. The damping is determined by the half width of the resonance peak. Experiments can be carried out from 10 cycles per second to several hundred cycles per second.

Better Ways of Evaluating

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DURING THE LAST TEN YEARS the use plastic materials has grown tremendously, both in the consumer and industrial fields. The main reasons for this growth are: (1) the relatively low cost of most of the important thermoplastic and thermosetting resins; (2) the low cost of conversion from the molding powder to the finished product, and (3) the wide range of mechanical properties which can be obtained by proper compounding and processing.

The third condition is of primary interest to the design and product engineer. The success or failure of a product depends to a great extent on the proper evaluation and interpretation of the mechanical properties.

Existing Test Methods

Mechanical tests on plastics are conducted for two reasons: (a) To give to the design engineer and the manufacturer of plastic articles information that can be used as a guide in the choice of the proper material for a particular design; and (b) to give the manufacturer of plastic raw materials information relating to the mechanical properties to the molecular structure and to such variables in the manufacturing process that have a definite bearing on these properties.

Stress-strain and ultimate strength properties have been and still are widely used to determine the use range of plastics. Some form of flow test has been the prevalent method of obtaining information on the behavior of plastics at elevated temperatures or in their processing range. These test methods were taken over by the plastics industry from the metal, wood, glass and rubber industries. It is questionable whether the data derived from these tests is as significant as indicated by their popularity. The separation of the intrinsic properties of the material from variables affecting the result is difficult, if not impossible. For example, impact testing is particu-

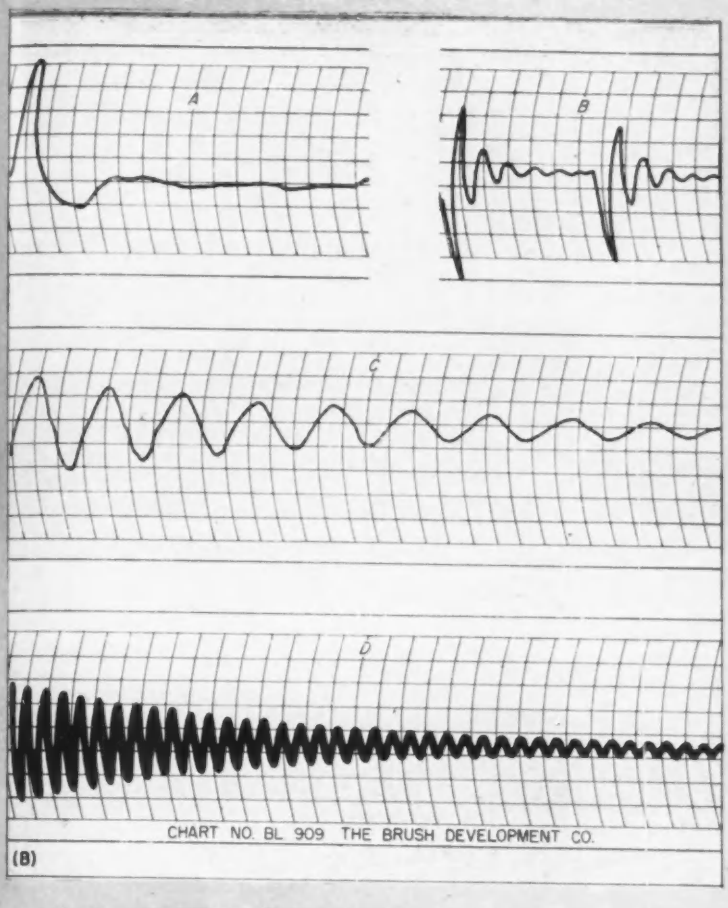

Fig. 2—Torsion Pendulum Apparatus (A). This instrument is used to measure dynamic shear moduli and damping. The plastic specimen is attached to a moment of inertia disk and is allowed to twist and untwist as it carries out free vibrations. The shear modulus is calculated from the frequency of the oscillations and damping is determined from the logarithmic decrement or the rate at which the oscillations diminish.

In this figure *A* is a fine suspension wire, *B* is the moment of inertia disk, *C* is the plastic specimen, *D* is the lower specimen clamp attached to shaft *E*. The shaft is mounted in ball bearings but is prevented from rotating by spring rods, *G*. However, very small angles of twist occur and move arm *J* to which is attached the iron core of the variable differential transformer *K*. This movement is eventually recorded on a magnetic type direct writing oscillograph (B). Since the movement of the core of the transformer is a direct indication of the oscillations taking place in the plastic specimen, the oscillograph chart gives a record of the twisting and untwisting of the specimen. Some typical results are shown. Curves A and B represent materials of very high damping. Curve C is for a rubbery material of moderate damping, and Curve D is for a rigid material of small damping. The torsion pendulum is useful for tests made at a frequency from 0.05 cps to several cycles per second.

Properties of Plastics

A real need exists for the development and use of instruments and methods that will give mechanical properties of plastics in terms of well defined physical quantities, and that cover the use and processing temperature ranges of plastic materials. Some of these methods have been developed.

larly dependent upon test conditions and very little specific information on the behavior of plastics under impact can be obtained.

Most methods of mechanical testing are set up to give results at one temperature and one humidity level. Since plastics are temperature dependent, mechanical testing should include a systematic study of properties as a function of temperature.

Dynamic Testing Methods

Dynamic methods for measuring certain mechanical properties of solids have certain advantages over static methods when applied to rigid or elastomeric plastics:

(1) The shear or Young's modulus can be evaluated independent of creep or flow effects.

(2) the damping capacity or dissipation factor can be obtained.

(3) measurements can readily be made over a wide temperature range using small amounts of material.

(4) the modulus and dissipation factor can be studied as a function of frequency.

Two instruments have been found particularly useful for the study of plastics materials—the resonating feed vibrator for measuring the modulus

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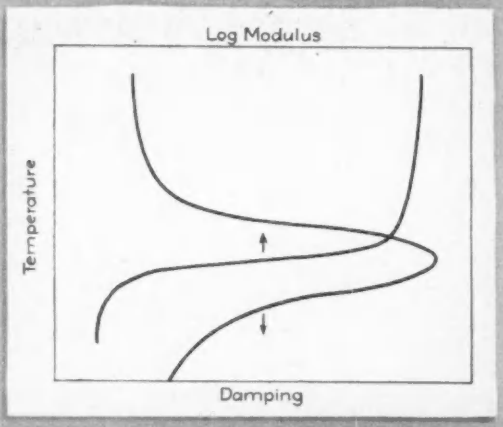

Fig. 3—Generalized dynamic modulus and damping curves.

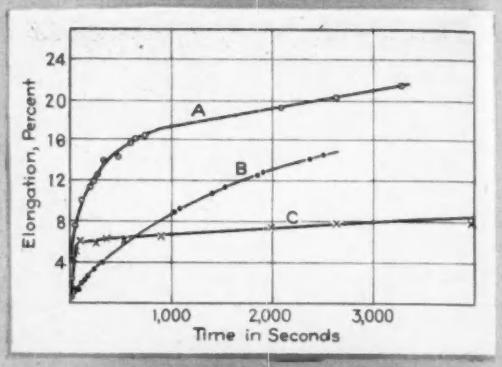

Fig. 4—Creep of plasticized polyvinyl chloride. Curve A signifies the rubbery region, curve B the transition region and curve C, the hard region.

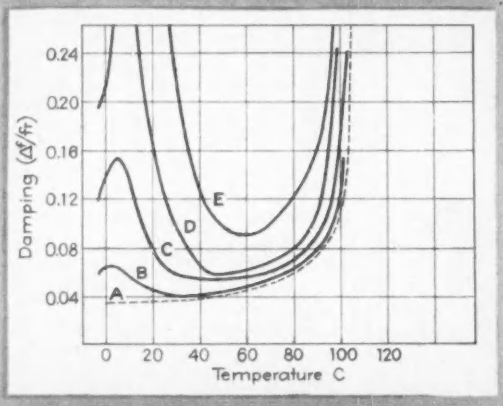

Fig. 7—Damping curves of mechanical blends of polymers showing more than one maximum over a reasonably wide temperature range.

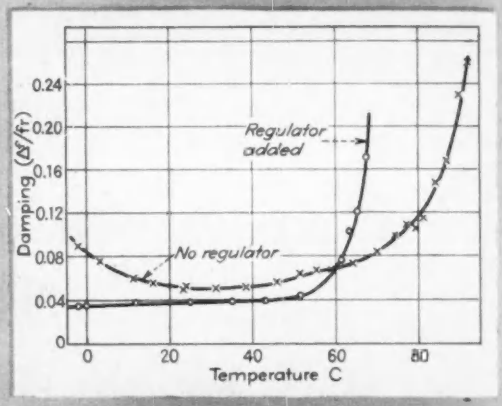

Fig. 8—Damping curves of two copolymers of same overall composition, polymerized in the absence and in the presence of a certain amount of regulator.

and dissipation factor of rigid plastics, and the torsion pendulum for measuring dynamic shear moduli and damping. These are illustrated and described in Figs. 1 and 2.

Much useful data can be obtained with these instruments. Fig. 3 shows a generalized dynamic modulus and damping curve as a function of temperature for a typical thermoplastic resin with little or no crystallinity. There is only one maximum in the damping curve for this material over a wide temperature range. Although the dynamic properties are somewhat frequency dependent, the most striking changes occur as the temperature is varied while the frequency is held approximately constant. Both curves can be divided into three regions: The low temperature or hard region having a high modulus and low damping, both quantities changing only slightly with temperature; the transition region where the modulus and damping change considerably within a narrow temperature range; and the rubbery or liquid region of low modulus and damping. Curves of this type have been determined for a large number of resinous compositions, both plasticized and unplasticized. They indicate that the significant differences in mechanical properties among large numbers of compounds are indicated by the position of the transition region on the temperature scale. Two quantities—the transition temperature, or temperature of maximum damping, and the width of the transition region —can be used to give an excellent qualitative characterization of the mechanical properties of polymer systems. On the low temperature side of the damping peak the material is hard and rigid and will break when stretched only slightly. In the transition region the material is leathery, and on the high side it will be rubbery and capable of great elongation before breaking.

Stress—Strain, Creep and Impact Properties

In addition to the qualitative data mentioned above it is possible to obtain specific information concerning mechanical properties such as creep rate, stress strain properties and impact behavior.

The creep rate of rigid thermoplastics, such as polystyrene, increases very rapidy with increased damping. The damping capacity and the creep rate do not show any appreciable variation between 0 and 50 C. However, at 80 or 90 C the damping starts to increase rapidly. A large increase in creep rate is also noted. It is possible to estimate the creep rate of a material from the value of the damping and to predict the shape of the

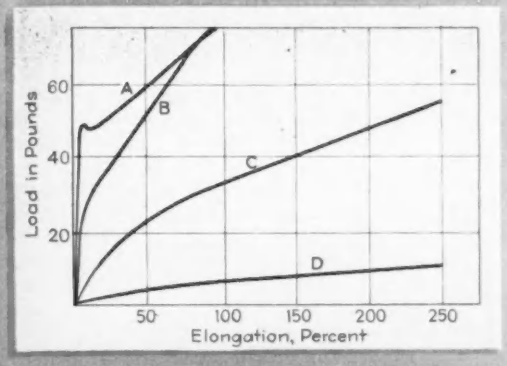

Fig. 5—Stress-strain curves of plasticized polyvinyl chloride at various temperature ranges. Curve A—below transition temperature; Curves B and C in transition range; Curve D—above transition temperature range.

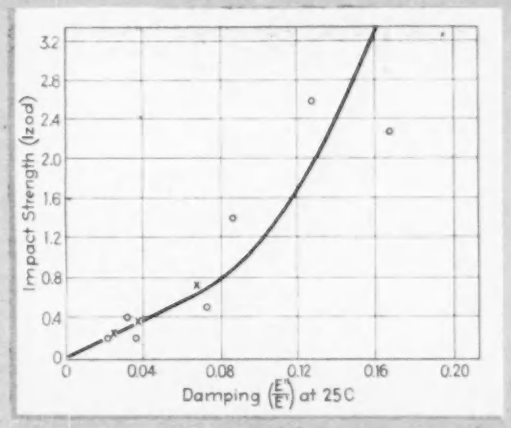

Fig. 6—Impact strength as a function of damping capacity.

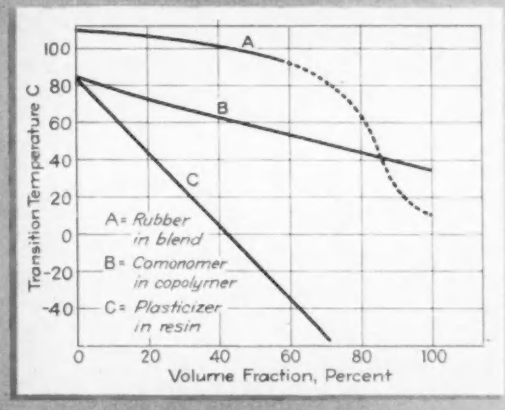

Fig. 9—Transition Temperature variation with addition of plasticizer, shown for three different compositions.

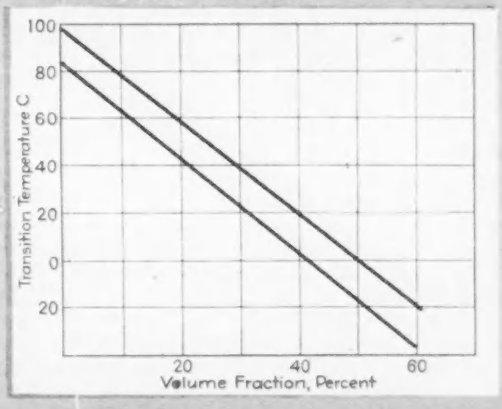

Fig. 10—Transition Temperature as a function of plasticizer concentration for polar materials. Upper curve for electrical case, lower curve for mechanical case.

creep curve from the damping curve. This is illustrated in Fig. 4 for a plasticized polyvinyl chloride composition at different temperatures.

At temperatures well above the transition range where damping is low (*A*), the material initially elongates rapidly and then levels off. In the transition region (*B*), damping is high and elongation is slight when the load is first applied. The creep, however, continues with time and gives no indication of leveling off. Below the transition temperature (*C*), there is again very little creep after the initial rapid elongation. Thus, the creep rate is greatest where the damping is greatest. This correlation between damping coefficient and creep rate or stress relaxation has been carried further in the case of rubber. Other investigations[6] have shown that one property can be calculated from the other with reasonably good agreement between the calculated and measured values.

In certain classes of plastics, the general shape of the stress-strain curve can be correlated with the damping curve. Fig. 5 illustrates this for various polyvinyl chloride compositions. If the tests are carried out at temperatures well below the transition temperature, the material has high tensile strength, low elongation, and may or may not show a yield point. Immediately below the transition temperature, Fig. 5 *A* the tensile strength is high, the elongation is greater, and a very distinct yield point is noted. In the transition region the elongation will increase and there will be a broad, indistinct yield point (*B* and *C*). At temperatures above the transition region, where the damping has become relatively small again, the elongation will be several hundred percent, the tensile strength will have decreased and there will be no indication of a yield point, (as shown in *D*). Young's modulus, as determined from the initial slope of the stress-strain curve, will have decreased in going through the transition region. The values correlate very well with the dynamic shear moduli obtained at the same temperature, the dynamic shear moduli being slightly lower. Within one class of materials and often between different classes of materials, it is possible to estimate the impact strength of plastics from the damping value. The correlation of impact strength with damping capacity is shown in Fig. 6. The agreement is surprisingly good when one considers the complex and arbitrary nature of the Izod impact test.

HEAT DISTORTION. A large number of test have been established in the plastics industry to measure a heat

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Table I—Correlation Between Initial Stress-Strain and Dynamic Modulus

Formulation No.	E/G (25°C.)	Region
1	2.68	Transition
2	2.68	Transition to Rubbery
3	1.59	Rubber
4	1.93	Hard
5	2.62	Transition to Rubbery
6	2.22	Transition to Rubbery
8	2.67	Rubber
9	1.24	Transition to Rubbery
10	2.09	Hard
13	2.86	Transition to Rubbery
14	1.52	Rubber
15	1.87	Transition
Unplasticized PVC	2.09	Hard

E = Stress-strain Young's modulus G = Dynamic shear modulus
E/G = 3 if Poisson's ratio = 0.5 and if other variables do not change.

distortion or softening point. Some of these are the *ASTM* heat distortion test, the brittleness test and the flex temperature. All these tests measure the position of the transition region on the temperature scale. However, these methods do not separate the two independent quantities which characterize transition: the transition temperature, and the width of the transition region. If the transition range is small, i.e., the dampening peak is sharp and narrow, all the softening temperatures will be close together. If the dampening peak is broad, the brittle and heat distortion point may be considerably below the temperature of maximum damping. The width of the damping maximum is important in many applications. For elastomeric products, it is a measure of the available temperature range before complete embrittlement sets in. The knowledge of this range can in some cases be just as important as the temperature of embrittlement.

Study of Other Effects

STRUCTURAL DIFFERENCES. It was pointed out above that a large number of polymeric systems have only one damping maximum. There exist, however, other systems which show two or more peaks. Fig. 7 shows the results obtained on a series of mechanical blends of polymers. More than one peak can also be observed in systems containing at the same time crystalline and amorphous region. The data given in Fig. 8 indicate that the damping is capable of revealing even finer differences in molecular structure. The two curves represent copolymers of the same overall composition polymerized in the absence and presence of a certain amount of "regulator."

The damping coefficient in polymeric systems appears to be an extremely sensitive tool for detecting certain structural differences on a molecular or colloidal scale. These can be recognized only with great difficulty by other methods. The application of dynamic methods to problems of structural analysis has been eminently successful in the field of metallurgy[7] and promises to be equally useful in the field of high polymers. These methods have also been most useful in studying the mechanism of plasticization. The efficiency of a given plasticizer can be evaluated from dynamic mechanical measurements by making use of the transition temperature as a function of the volume fraction of the plasticizer as shown in Fig. 9. This makes it possible to predict the effect of plasticizer concentration from a knowledge of the transition of the unplasticized resin and one plasticizer-resin composition.

ELECTRICAL PROPERTIES. For polar materials the similarity of the electrical and mechanical behavior is remarkable. The electrical power factor vs temperature curve goes through a maximum similar to the mechanical damping. The dielectric constant-temperature curve has a sigmoidal shape like the inverse of the modulus curve. Although the power factor peak is broader than the damping peak, there is approximately a linear relationship between the two. The position of both these peaks can be shifted on the temperature scale by the addition of a plasticizer. The slope of the transition temperature vs concentration of plasticizer curve is identical for the mechanical and electrical cases, Fig. 10. One of the reasons why the electrical transition temperature is higher than the mechanical one is because the electrical tests were carried out at 1,000 cycles per second while the mechanical tests were carried out at about 0.1 cycles per second.

OTHER EFFECTS. Other important properties and effects can be studied with an instrument known as a rotational viscometer—the details of which have not been included in this article. Its functions are to obtain useful information concerning the effect of molecular deformation and to reveal details about the existence of network structure in thermoplastics and non-permanently cross-linked polymers, such as polystyrene.

The data obtained by the methods described are also of value in correlating mechanical properties with the molecular or the colloidal structure of polymer compounds. All data obtained can be expressed in terms of well defined physical quantities, which is not the case in many of the more common tests in use in the plastics industry. The importance of this fact is readily appreciated when one considers that it is impossible to attempt even a theoretical interpretation of data which cannot be expressed in such a manner and which contain implicitly the effect of instrument variables.

Information included in this article was presented to indicate that methods capable of giving results of well defined physical significance, such as dynamic modulus, dynamic damping and viscosity are not only useful in the study of mechanical properties and their relation to molecular structure but also give information concerning the use and application of plastic materials. The specific methods discussed are not the only ones that could or should be used; what is important is the attitude and approach to mechanical testing embodied in the use of methods of this kind and in the interpretation of the results.

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Hydraulic Noise Reduction by Capacitive Load Chamber

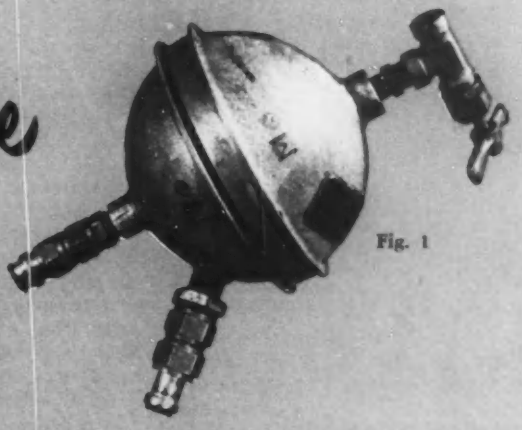

Fig. 1

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Table I

Accumulator Air Charge, psig	Pump Pressure Rise, psi	Energy Diversion from Line, percent	Volume of oil in Accumulator cu. in.
100	105	75.0	47.3
100	400	87.9	53.1
100	800	89.7	59.3
100	1200	96.9	64.5
Zero	105	81.6	62.4
Zero	400	90.5	63.2
Zero	800	96.7	64.0
Zero	1200	93.4	64.8

Results of test run on capacitive reactance chamber, Fig. 1. Frequency was 200 cycles/sec.

How to determine size requirements for capacitive load chambers. Effect of such chambers on the pump pressure waves that cause hydraulic noise and circuit destruction. Charts for quickly approximating effective chamber volume. Second in a series of three articles on reducing noise in hydraulic systems.

DAMAGE TO HYDRAULIC SYSTEM COMPONENTS caused by pump pressure waves can be prevented by blocking or reducing the amplitude of these waves to a minimum. One way of accomplishing this is to include a capacitive loading chamber in the discharge line from the pump.

A capacitive loading chamber is simply a bulge in the line in which wave energy can be dissipated. Properly designed, such chambers in some instances reduce port waves amplitudes as much as 97 percent. The chamber shown in Fig. 1 was used in experiments to determine the effectiveness of capacitive loading for noise reduction in hydraulic systems. It consists of a 5 in. hydraulic accumulator modified to be put in parallel with the line without disturbing the internal elastic diaphragm. The oil volume of the chamber was reduced by air pressure to the under side of the elastic diaphragm. The results of tests performed on this device shown in Table I support the theoretical analysis offered here.

Port Wave Theory

Before the basic theory and design data of capacitative loading chambers can be wisely applied, an understanding of port wave production and approximate determination of wave energy is necessary.

The pump may be considered as a sound source yeilding sinusoidal variations in pressure and fluid displacement. Actually, this is complicated by the rich variety of frequencies existing in pump noise, but the concept of an equivalent simple wave of energy transfer rate is a necessary simplification. Actual wave shape and amplitude are not required in an energy solution for finding the ideal chamber volume.

The power output of this equivalent simple wave is:

$$S = \frac{dE}{dt} = 1/2\ P_e \Delta \qquad (1)$$

where:

P_e = effective pressure amplitude
Δ = maximum fluid displacement rate, during oscillation
E = potential energy stored in fluid during exposure of pump cylinder to line pressure at time of discharge. To be released in system in wave form.
t = time interval of energy induction or dissipation.

Considering a section of fluid having unit area and extending down-stream

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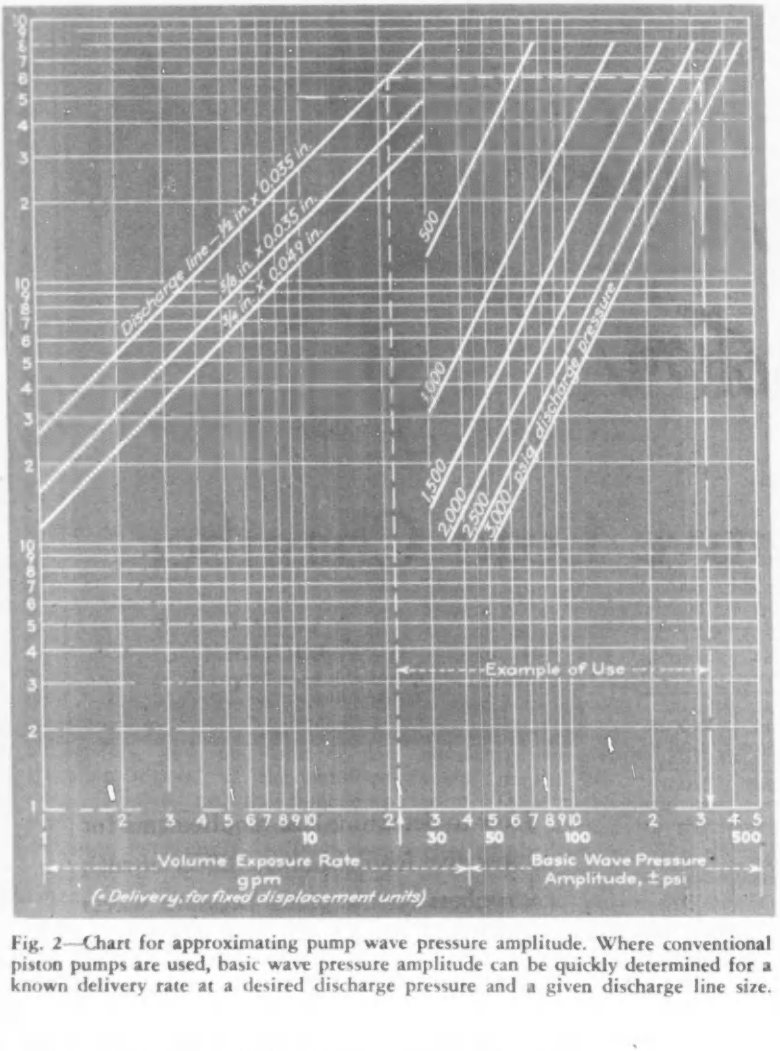
Discharge line – ½ in. x 0.035 in.
⅝ in. x 0.035 in.
¾ in. x 0.049 in.
500
1,000
1,500
2,000
2,500
3,000 psig discharge pressure
Example of Use
1 2 3 4 5 6 7 8 9 10 20 30 40 50 60 70 80 90 100 200 300 400 500
Volume Exposure Rate gpm
(+Delivery, for fixed displacement units)
Basic Wave Pressure Amplitude, ± psi

Fig. 2—Chart for approximating pump wave pressure amplitude. Where conventional piston pumps are used, basic wave pressure amplitude can be quickly determined for a known delivery rate at a desired discharge pressure and a given discharge line size.

from the pump port, (x) distance,

$$\Delta = \frac{dV}{dt} = \text{volume rate, by definition}$$

$$\Delta = \frac{dV}{dx} \cdot \frac{dx}{dt} = C' \cdot \frac{dV}{dx}$$

$$\frac{C' P_e}{K'} \qquad (2)$$

V = Volume of fluid displaced by pressure wave.

C' = 37,800 in./sec. C' = Wave velocity in fluid when confined in tubing

K' = 180,000 psi = Bulk modulus of elasticity, psi of fluid. For AN-VV-O-366 hydraulic oil, at 150 F.

$\rho = 76.2 \times 10^{-6}$ lb.-sec.^{2}/in.^{4} Mass density

$\sqrt{K'/\rho} = C = 48{,}600$ in./sec. for acoustic velocity in the unconfined fluid. In the tubing the lower figure (C'), directly determined by experiment, reflects the effects of tubing yield, oil viscosity, heat transfer and normally irreducible air content.

Therefore from Eq (1) and (2) *unit* source power is:

$$\bar{S} = \frac{C' P_e^2}{2 K'} \text{ in.-lb./sec./in.}^2 \qquad (3)$$

An alternative statement of pump acoustic power is the potential energy per pulse multiplied by the frequency, or number of pulses per unit time. The energy term may be expressed as:

$$E = \frac{P_D^2 - P_N^2}{2 K'} \cdot V$$

P_N = inlet pressure, psi.

P_D = discharge pressure, psi.

The mean energy rate or power is:

$$\frac{dE}{dt} = \frac{P_D^2 - P_N^2}{2 K'} \cdot \left(\frac{dV}{dt}\right)'$$

The term $(dV/dt)'$ is the mean volume rate of exposure of low-pressure oil to high-pressure oil. It depends on the clearance volume for fixed-displacement pumps and on both the clearance and in piston position for variable-displacement pumps.

A fixed-displacement pump delivering (Q) gpm has

$$\left(\frac{dV}{dt}\right)' = \frac{1.1 \times 231}{60} Q = 4.24 Q \text{ cu. in./sec.}$$

allowing 10 percent for clearance. The corresponding figures for a variable-displacement pump with maximum delivery of Q gpm would then be:

$$\left(\frac{dV}{dt}\right)' = 4.24 Q \text{ for full flow}$$

and for pumps operating fully feathered:

$$\left(\frac{dV}{dt}\right)'' = \frac{0.1 + 0.5}{0.1 + 1.0} \times 4.24 Q = 2.32 Q \qquad (5)$$

To Determine Wave Amplitude

For simplicity and practical meaning, the ensuing discussion assumes a pump operating at either a fixed or a maximum delivery. Thus, the theoretical acoustic power from the pump becomes

$$\frac{dE}{dt} = S = 2.12 (P_D^2 - P_N^2) \cdot \frac{Q}{K'} \text{ in.-lb./sec} \qquad (6)$$

all of which is conservatively considered to enter the discharge line in the form (see Eq. 1 & 2)

$$S = \bar{S} \cdot A = \frac{C' A}{2 K'} P_e^2 \qquad (7)$$

where

A = cross sectional area of discharge line

Equating expressions (6) and (7) the effective pressure amplitude is

$$P_e = \pm 2.06 \sqrt{\frac{(P_D^2 - P_N^2) Q}{C' A}} \qquad (8)$$

By inserting numerical limits for (P_D) and (P_N) covering the present range of service values, this equation may be put in a still simpler form using the customary *gauge* discharge pressure thus:

$$P_e = \pm (0.0107 \sqrt{\frac{Q}{A}}) \times (P_D')$$

This simple approximation involves less than 1 percent error throughout the normal field of values. Fig. 2 gives a graphical solution for the amplitude over the normal range of flow, line size and discharge pressure. It is to be emphasized that amplitude figure obtained thus are basic or nominal values. In several instances, experimental and computed (effective) amplitudes checked within 3 percent but the tests as a whole showed pressure amplitudes considerably higher than the effective values.

Capacitive Reactance Theory

When a lumped capacitance is inserted in the line, there results the acoustic equivalent of a parallel reactance circuit. The actual acoustic elements are as sketched in Fig. 3.

Consider a pressure wave to enter such a chamber, with the main line continuing out of another port. The ensuing action will be the expenditure of wave energy in some combination of chamber oil compression and pipe oil acceleration (and compression). What this combination will be evidently depends upon the relative opposition encountered in the two modes of behavior. In the most general case, the measure of this consists of the two impedances involved, but in the present instance the resistance components (viscous attenuation) are slight enough that study of the reactive components will suffice. The reactance of the oil-filled chamber is

$$X_c = -\frac{K'}{V} = -\frac{K'}{2\pi f V} \qquad (9)$$

where

$f = \frac{Nn}{60}$ wave frequency cps.

N = number of cylinders in pump

n = speed of pump (rpm)

V = chamber volume

X_c = chamber reactance

X_L = line reactance

The negative sign is the usual phase convention. The line's reactance may be expressed as:

$$X_L = \frac{2\rho L f}{A} = \frac{K'}{2\pi L A f} \qquad (10)$$

wherein (L) and (A) are the length and section area of the line leading out of the chamber. The reactance of the line increases and becomes dominantly in inertia effect, as frequency is raised, while the chamber's (capacitative) reactance decreases with frequency. Since the fluid motion and energy of the wave are propagated primarily into the field of least reactance, the wave is effectively diverted into the chamber and only a small pulse is transmitted down the line. Ultimately, actual attenuation must occur in the chamber, else the intensity therein would rise to a degree giving unimpaired transmission down the line. The size, shape and nature of the chamber walls all affect the results to the extent that they affect absorption and successive reflection. Whatever these characteristics are, in a given case, sound intensity in the chamber will rise until energy rejection is in equilibrium with the source and it is the equilibrium pressure amplitude which is transmitted downstream.

Relationship Between Pump Wave Amplitude and Residual Wave

The summation of alternating oil flow relative to normal pump discharge and corresponding to the port wave pulsation is

$$q_i = q_c + q_L \qquad (11)$$

q_i = alternating flow input

q_c = alternating flow in chamber

q_L = alternating flow in downstream line.

The factors q_L and q_c are inversely proportional to corresponding reactances and are related by

$$\frac{q_L}{q_c} = \frac{X_c}{X_L} \text{ or: } q_L = q_c \frac{X_c}{X_L}$$

From Eq (11),

$$q_i = q_c \left(1 + \frac{X_c}{X_L}\right)$$

$$= q_c \frac{X_L + X_c}{X_L} \qquad (12)$$

The residual wave amplitude R in the line from the chamber will be the same as in the chamber. Therefore the power relation or energy diversion relation is

$$S = P q_i = R q_c \left(\frac{X_L + X_c}{X_L}\right)$$

From Eq (7) and Eq (8) then

$$S = \frac{C' A P_e^2}{2 K'} = R^2 \left(\frac{X_L + X_c}{X_L X_c}\right) \qquad (13)$$

The output/input energy transmission is

$$e = \left(\frac{R}{P_e}\right)^2 \qquad (14)$$

or, from the power summation Eq (13),

$$e = \frac{C' A}{2 K'} \left(\frac{X_L \cdot X_c}{X_L + X_c}\right)$$

The combined reactance expression may be rewritten as:

$$\frac{X_L X_c}{X_L + X_c} = X_c \frac{1}{1 + \frac{X_c}{X_L}}$$

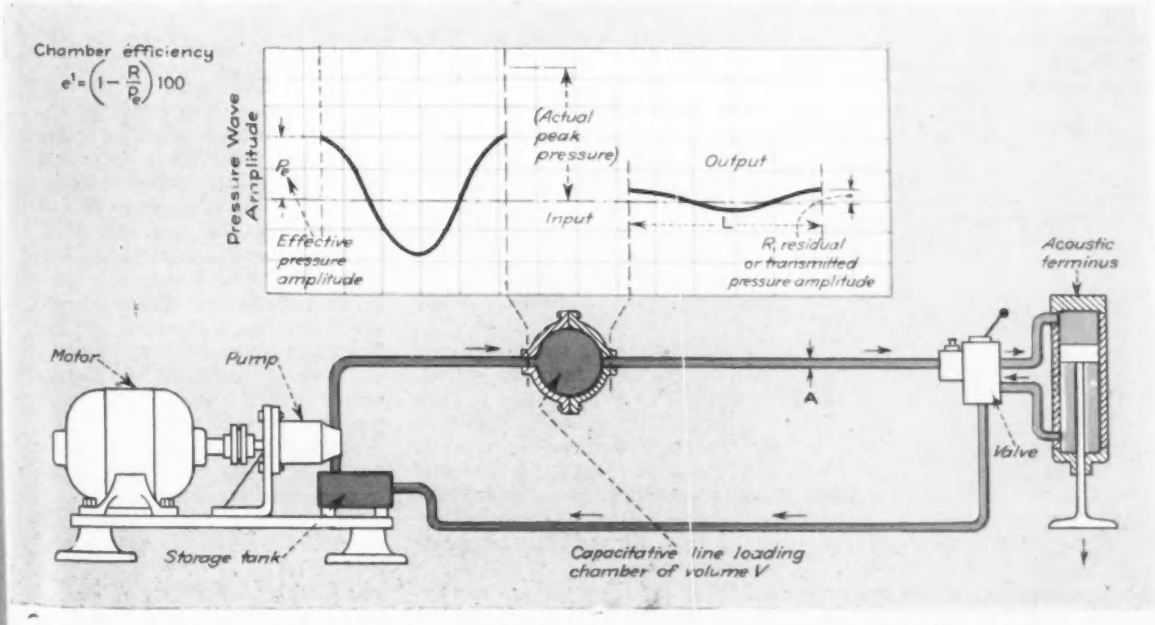

Fig. 3—Schematic diagram of hydraulic system with capacitive load chamber in pump discharge line. Variations in system performance complicate the actual wave form but for theoretical analysis the effective wave can be resolved to a simple sinusoid.

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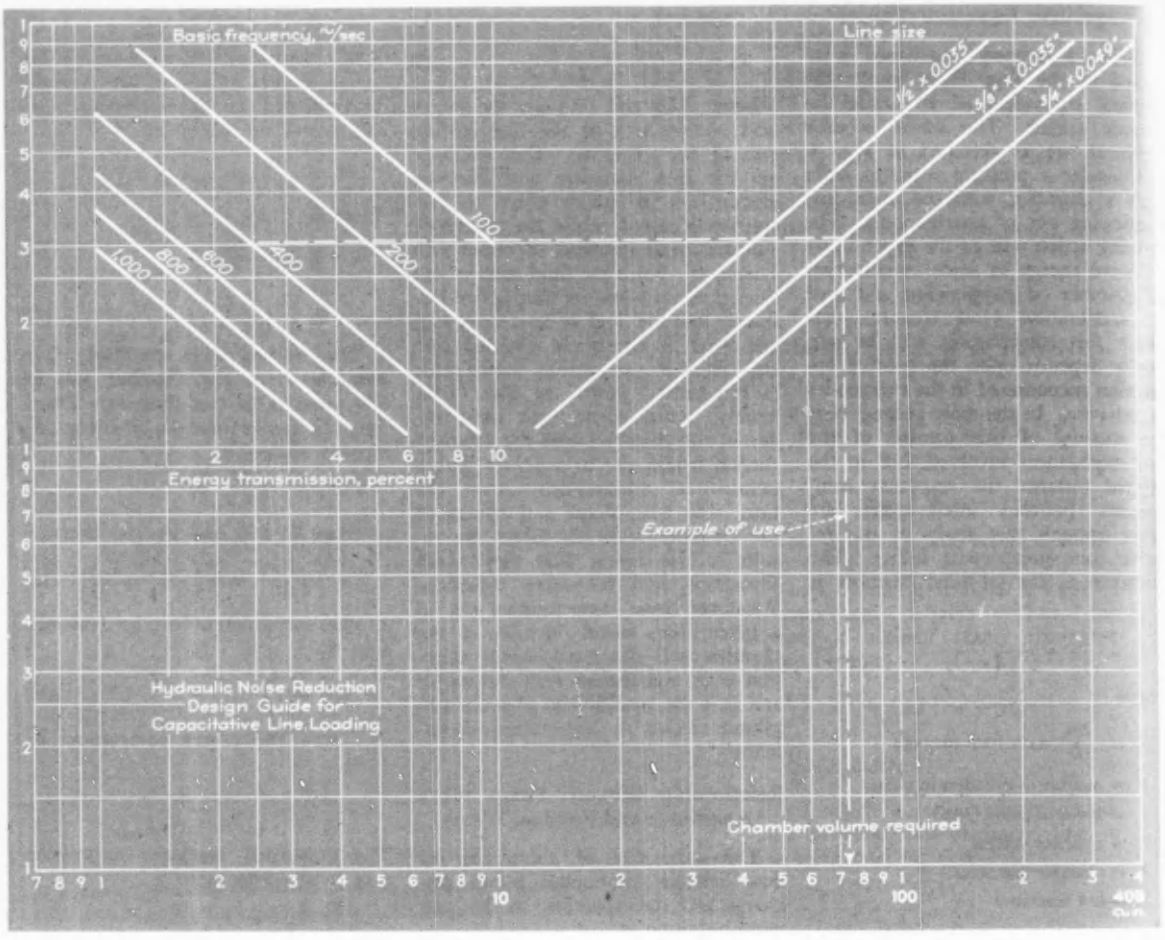

Fig. 4—Chart for determining the volume of a capacitive load chamber for a desired energy transmission ratio, where wave frequency and the pump discharge line sizes are known. In example, frequency is 400-cps and pump has a $\frac{3}{4}$ in. discharge.

For all useful values of e, < 10 per cent, the fraction $(X_e/X_L) \rightarrow 0$, giving the very close approximation

$$e \approx \frac{C' A X_e}{2 K'} \qquad (15)$$

The convenience of this is that downstream line length (L) need no longer be stipulated in a given problem

Substituting Eq (9) in Eq (15) the expression for required chamber volume is:

$$V = \frac{C' A}{4 \pi f e} \qquad (16)$$

The minus sign is omitted, since it only indicates phase.

Fig. 4 gives a convenient graphical association of (e) and (V), for the usual range of (f) and (A). The dead-reckoning aspect of all this calculation is redeemed by experimental results; several chambers of different size and shape were tested under a variety of conditions and the discrepancies between calculated and actual performance remained in the range 0.5 to 5 percent.

Oscilloscope studies showed that for e $<$ 10 percent, the output wave is a clean sinusoid; no matter how ragged and peaked the input, no transmission of higher orders was evident. This fact permits a rational choice of maximum acceptable (e), meaning minimum volume (V). The choice should be based on these considerations:

1. For the forcing frequencies common in commercial hydraulic systems, the rate of change of pressure is a better guide than pressure amplitude, for avoiding conditions conducive to system damage. For oil in a normal state, a safe upper limit for (dP/dt) is 500,000 PSI/sec. This is an empirical figure derived from laboratory work. The main limit on (dP/dt) is instability of dispersed air content. The oil density, compressibility, viscosity and surface tension are all involved and the rational derivation of critical (dP/dt) appears to be almost hopeless.

2. Allowance must be made for resonance amplification of the transmitted wave pressure (R). Detailed appraisal of this for a specific system is a fantastic problem of network analysis, which is advisable to evade by assuming the existence of the maximum possible amplification factor (m). The factor is definitely limited by oil viscosity and tubing hysteresis, while declining with rising frequency. Numerous tests featuring deliberate and precise resonance in favorably simple hydraulic lines showed a safe top value of ($m = 8$). Actually, it is difficult to exceed a value of ($m = 6.5$), but the higher value is recommended for this purpose.

With these data in hand, it is easy to set a (conservative) value for allowable (R).

$$\text{Max. } (dP/dt) = (mR)\,\omega = 2\pi f\, m\, R = 500{,}000$$

$$\text{and } R = \frac{500{,}000}{16\ f} = \frac{9940}{f} \qquad (17)$$

Design Example

To illustrate this method of reducing objectionable wave pressures, below is a design example appropriate to the hydraulic system of a commercial type airplane.

System Data: line size = 5/8" × 0.035"
P_D = 1700 psig
Condition A: Low cruising speed.
N = Pump rpm = 1.4 (engine rpm)
= 2240
n = 9 cylinders

Pump displacement: 90 percent feathered, (operating control boosters only).

Note: By Eq (5) this gives an exposure rate for cylinder oil amounting to:

$$\left(\frac{dV}{dt}\right)' = Q' = \frac{0.1 + (2 - 0.90) \times 0.5}{0.1 + 1.0} \times \frac{2240 \times 1.52}{231}$$

$$= 8.71 \text{ gpm}$$

To compute required volume (V) for this flight condition:

$$f = \frac{2240 \times 9}{60} = 336 \text{ cps}$$

by Eq (17)

$$R = \frac{9940}{336} = \pm 29.6 \text{ psi, maximum allowable}$$

Entering Fig. 2 at 8.71 gpm, the basic wave pressure is read as:

$P_e = +110$ psi

whence the required transmission ratio is:

By Eq (14) $e = \left(\frac{R}{P_e}\right)^2 \times 100 = 7.25$ percent

and by starting with this (e) value on Fig. 4, the corresponding required volume for condition (A) is:

$V_A = 30$ in.^{3}

Before choosing this, consider some other flight conditions.

Condition B: High cruising speed.
N = 3080 rpm
Q' = 11.97 gpm and f = 462 cps
From Fig. 2, $P_e = \pm 130$ psi
and $R = \frac{9940}{462} = \pm 21.5$ psi

whence: $e = \frac{21.5}{130} 2 = 2.73$ percent

From Fig. 4 at 2.73 percent
$V_B = 56$ in.^{3}

Finally, consider the critical but transient *Condition C:* Take-off, with concurrent retraction of landing gear and flaps.

N = 3920 rpm
Q = full displacement = 25.8 gpm
P_D = 1400 psig
f = 588 cps, so $R_{max} = \pm 16.9$ psi
$R = \pm 16.9$ psi

On Fig. 2,

$P_e = \pm 150$ psi

$e = \frac{16.9}{150} 2 = 1.27$ percent, whence Fig. 4 indicates

$V_C = 97$ in.^{3}

In point of weight, bulk and acoustic performance, the most efficient chamber shape is spherical. The values of ID for these three cases are:
For Condition A, sph. ID = 3.85 in.
For Condition B, sph. ID = 4.75 in.
For Condition C, sph. ID = 5.70 in.

Considering the transient nature of Condition C, the practical answer for the application is B, the 4.75 in. sphere. Before concluding this, however, the effect of imposing take-off conditions upon Chamber B should be examined. Thus, working backward through Fig. 4 by entering it at (V = 56 in.^{3}), the revised value for transmission at take-off appears as

$e_c' = 2.25$ percent

whence

$R' = P_e/e' = 150 \times 0.15 = \pm 22.5$ psi

This is ⅓ greater than the calculated value for *sustained* safe operation, which is not serious for short runs.

It should be recalled that line loading does not eliminate wave energy; it merely confines most of the energy to the vicinity of the pump. The *pump* still takes a beating.

The first article of this series of three on noise in hydraulic systems was published in February PRODUCT ENGINEERING. It covered port wave generation and how piston pumps can be modified to eliminate or at least minimize the amplitude of these waves at their source.

The third article of the series to be presented in the April issue will show how air in hydraulic oil effects noise in the system and what measures can be taken in system design to minimize these effects.

Noise in Hydraulic Systems

		RESULTS
EFFECTS	Energy loss	Excessive oil temperatures. Inefficient transfer of power.
	Circuit destruction	Cavitational corrosion of fittings. Aggravates leaks at joints and seals. Too rapid pressure gage deflection. Jerky mechanism operation.
	Personal discomfort	Operator fatigue. Errors in operating because of failure to hear instructions. Passenger discomfort (aircraft and automobiles).
CAUSES	Pump waves	Produced by pump or motor when elastic fluid in cylinder is compressed by high pressure discharge oil and rebounds into discharge line.
	Air in oil	Amplifies pump waves. Entrained air causes cavitation. Dissolved air increases elasticity of fluid.
CORRECTIONS	Pump alterations	Provides means of fluid precompression in pump by increasing compression lap of piston discharge stroke.
	Capacitive loading chamber	Provides volume in pump discharge line where port wave may be dissipated. Must be of correct volume.
	Fluid conditioning	Fill system with care to keep quantity of dissolved and entrained air to minimum. Reduces cavitation coefficient.

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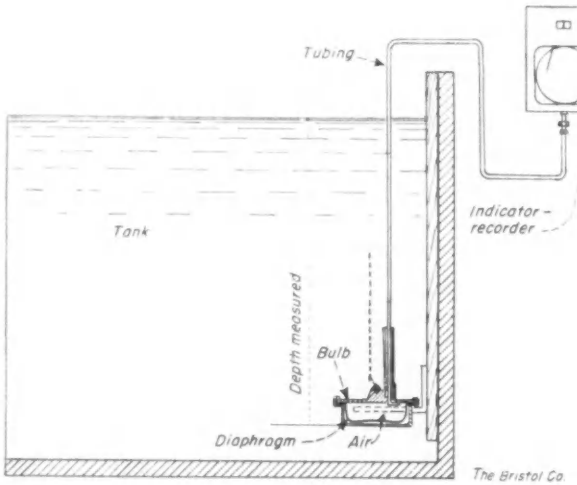
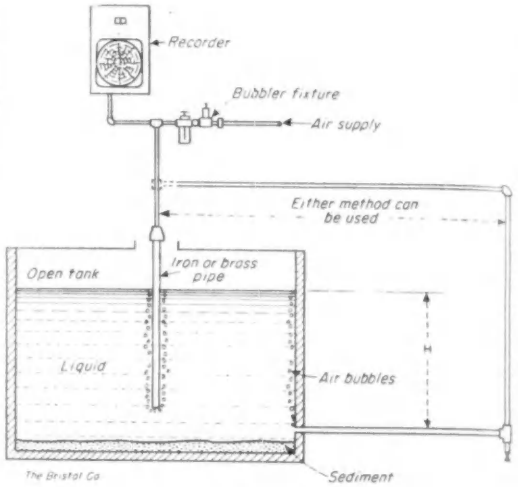
Liquid Level Indicators and

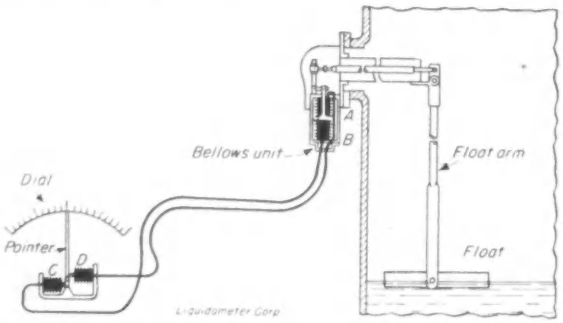
Thirteen different systems of operation are shown. Each one represents at least



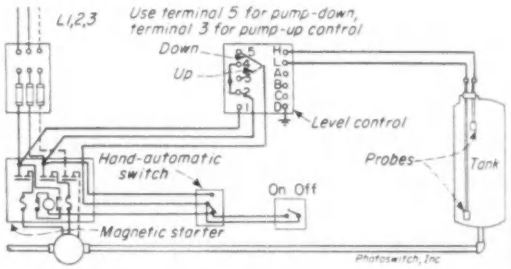
DIAPHRAGM ACTUATED INDICATOR. Can be used with any kind of liquid, whether it be flowing, turbulent, or carrying solid matter. Recorder can be mounted above or below the level of the tank or reservoir.



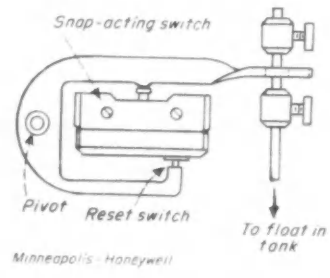
BUBBLER TYPE RECORDER measures height *H*. Can be used with all kinds of liquids, including those carrying solids. Small amount of air is bled into submerged pipe. Gage measures pressure of air that displaces fluid.



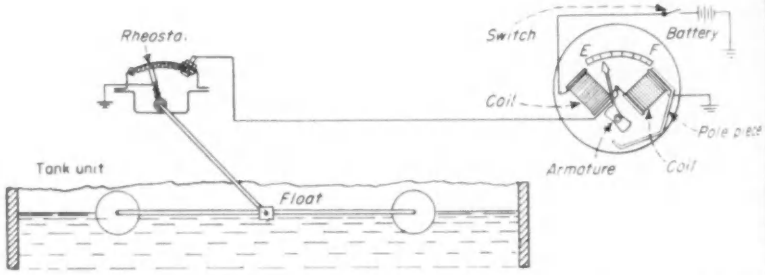
BELLOWS ACTUATED INDICATOR. Two bellows and connecting tubing are filled with incompressible fluid. Change in liquid level displaces transmitting bellows and pointer.



ELECTRICAL TYPE LEVEL CONTROLLER. Positions of probes determine duration of pump operation. When liquid touches upper probe, relay operates and pump stops. Through auxiliary contacts, lower probe provides relay holding current until liquid drops below it.



FLOAT-SWITCH TYPE CONTROLLER. When liquid reaches predetermined level, float actuates switch through horseshoe-shape arm. Switch can operate valve or pump, as required.

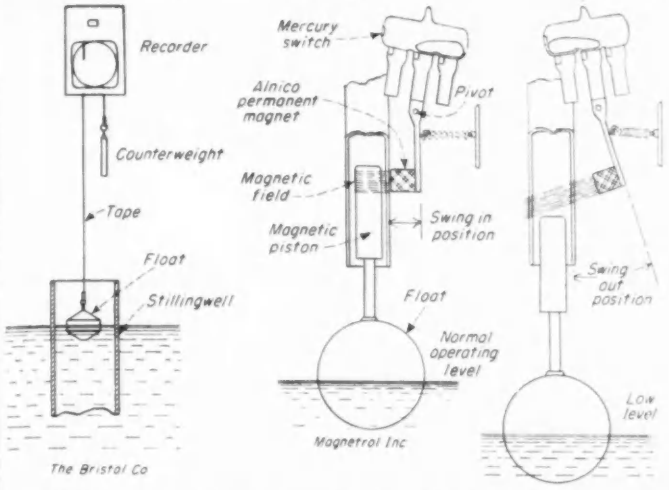


AUTOMOTIVE TYPE LIQUID LEVEL INDICATOR. Indicator and tank unit are connected by a single wire. As liquid level in tank increases, brush contact on tank rheostat moves to the right, introducing an increasing amount of resistance into circuit that grounds the "F" coil. Displacement of needle from empty mark is proportional to the amount of resistance introduced into this circuit.

Controllers

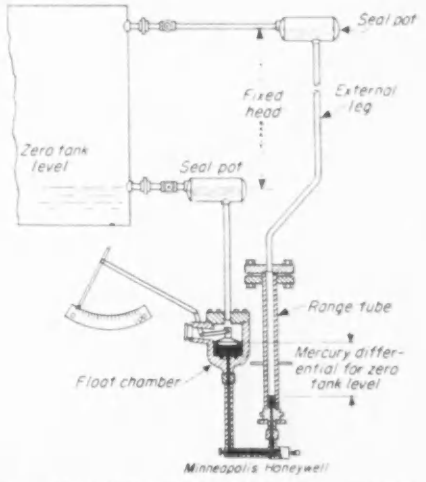
H. W. HAMM

one commercial instrument. Some of them are available in several modified forms.

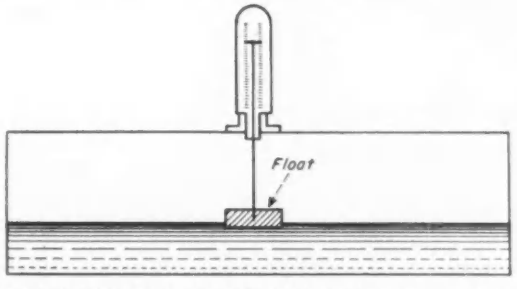


FLOAT TYPE RECORDER. Pointer can be attached to a calibrated float tape to give an approximate instantaneous indication of fluid level.

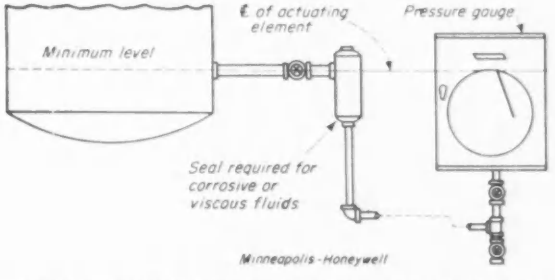
MAGNETIC LIQUID LEVEL CONTROLLER. When liquid level is normal, common-to-right leg circuit of mercury switch is closed. When level drops to predetermined level, magnetic piston is drawn below the magnetic field.



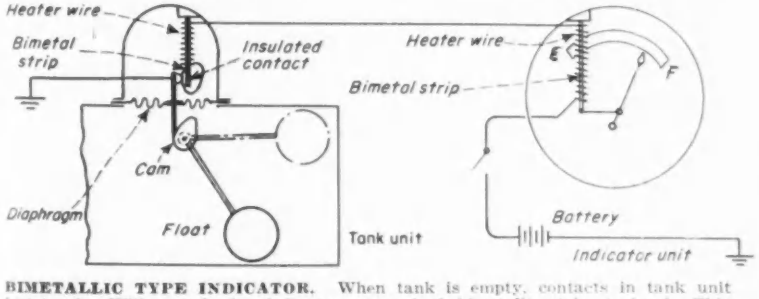
DIFFERENTIAL PRESSURE SYSTEM. Applicable to liquids under pressure. Measuring element is mercury manometer. Mechanical or electric meter body can be used. Seal pots protect meter body.



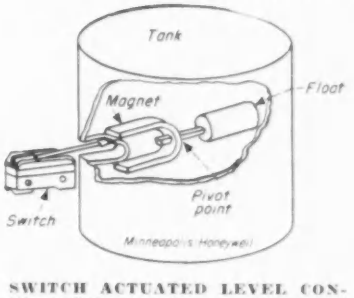
DIRECT READING FLOAT TYPE GAGE. Inexpensive, direct-reading gage has dial calibrated to tank volume. Comparable type as far as simplicity is concerned has needle connected through a right-angle arm to float. As liquid level drops, float rotates the arm and the needle.



PRESSURE GAGE INDICATOR for open vessels. Pressure of liquid head is imposed directly upon actuating element of pressure gage. Center line of the actuating element must conincide with the minimum level line, if the gage is to read zero when the liquid reaches the minimum level.



BIMETALLIC TYPE INDICATOR. When tank is empty, contacts in tank unit just touch. With switch closed, heaters cause both bimetallic strips to bend. This opens contacts in tank and bimetals cool, closing circuit again. Cycle repeats about once per sec. As liquid level increases, float forces cam to bend tank bimetal. Action is similar to previous case, but current and needle displacement are increased.



SWITCH ACTUATED LEVEL CONTROLLER. Pump is actuated by switch. Float pivots magnet so that upper pole attracts switch contact. Tank wall serves as other contact.

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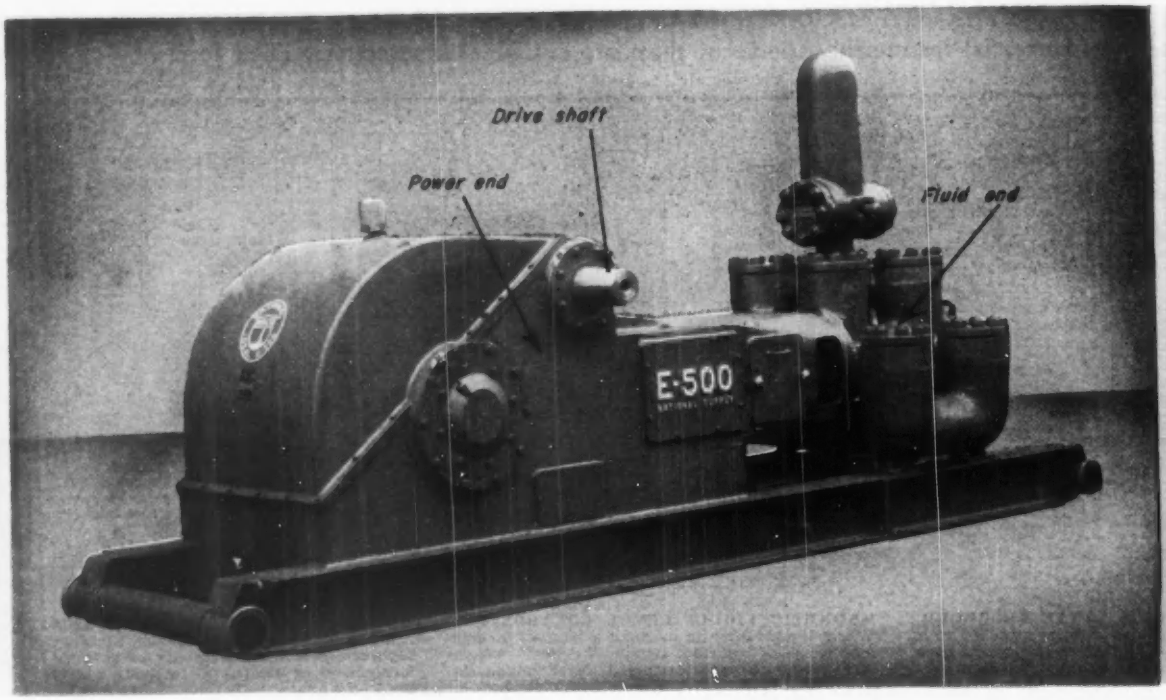
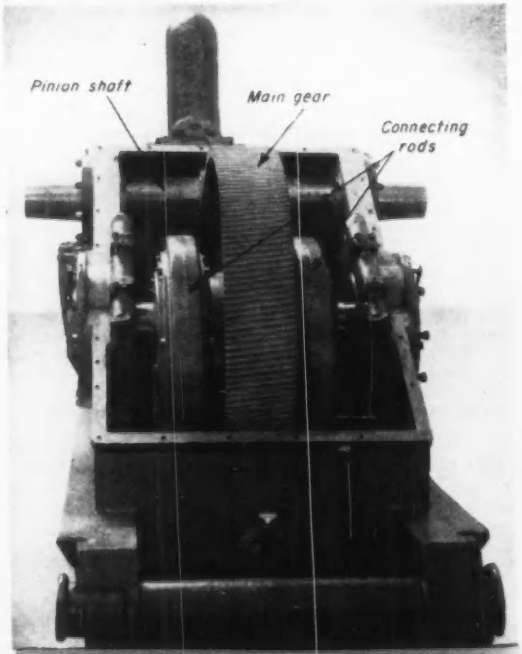


Welded Construction Reduces Pump Weight

Engineers of The National Supply Company in Toledo, Ohio have designed a new 500 hp slush pump using a welded steel design to reducce weight without sacrificing strength or performance. The weight of this new Ideal Model E-500 pump is 34,000 lb, whereas an Ideal pump of older design is rated at 385 hp and weighs 37,500 pounds.

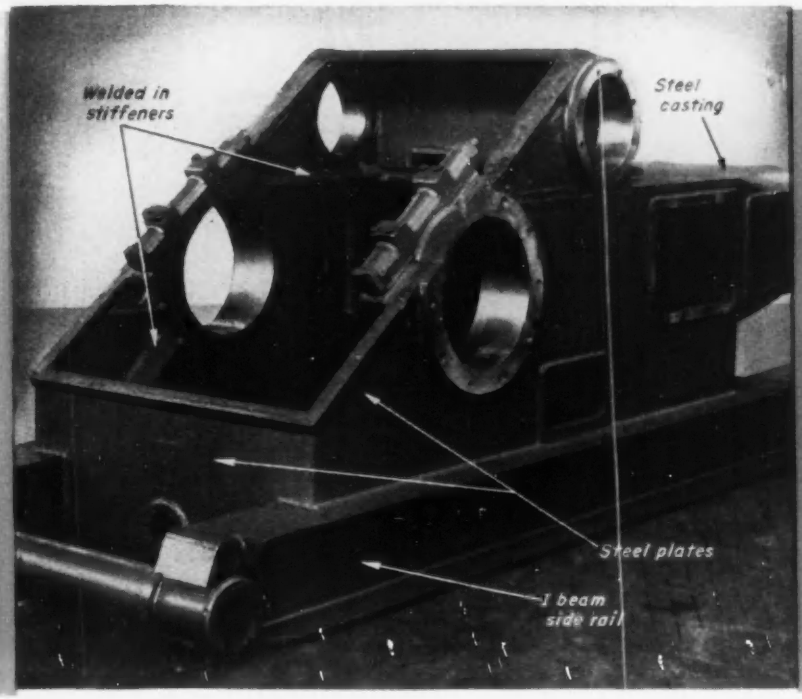
These pumps are used on oil well drilling rigs to circulate the very abrasive drilling fluid at high pressures. Any reduction in pump weight increases the ease with which the pump can be moved from one drilling site to another.

The pumps are built in two sections and are bolted together. The pump section or fluid end contains the cylinders, pistons, valves and air chamber all housed in steel castings. Most of the changes were made in the crank section or power end of the pump. The main frame combines steel castings and steel side plates with I beam side rails to form the unit housing. Moving parts that are now of welded construction, are the main drive gear and the eccentric shaft assembly.



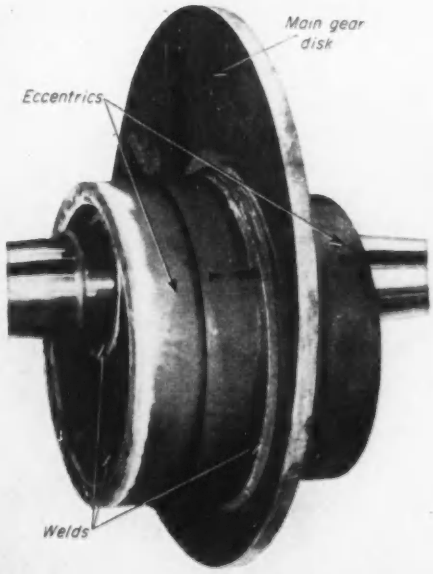
REAR VIEW of power end with the gear cover removed. The pinion and pinion shaft are an integral heat treated alloy steel forging. The main gear is a welded assembly and is bolted to the eccentric unit.

IN NEW PRODUCTS

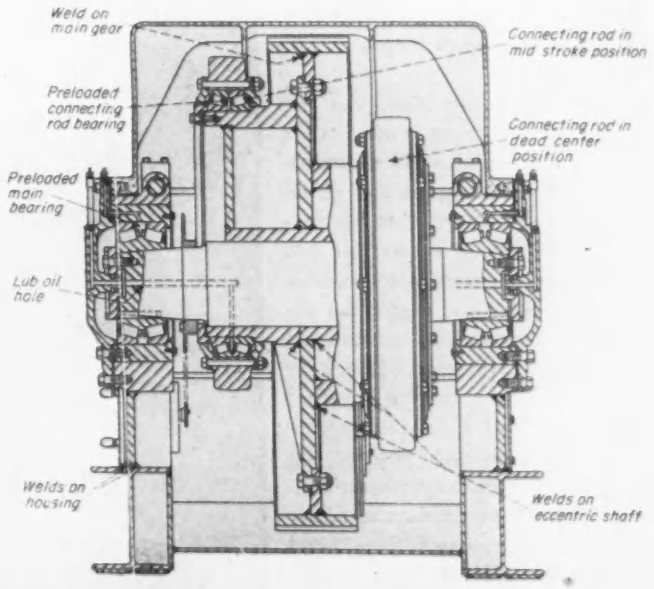


OIL WELL slush pump at left shows how welded steel construction can be integrated with steel castings to increase the strength yet reduce the weight of this type machine.

JIG-WELDED main frame is made of steel plate, steel castings and steel beam skid-rails. The welded stiffeners strengthen the main frame and minimize deflections caused by the heavy loads imposed during operations.



THE ECCENTRIC shaft assembly is a weldment of rolled steel forgings and steel plate mounted on a forged steel shaft. It is shown here prior to machining the disk and eccentrics.


Weld on main gear
Connecting rod in mid stroke position
Preloaded connecting rod bearing
Connecting rod in dead center position
Preloaded main bearing
Lub oil hole
Welds on housing
Welds on eccentric shaft

VERTICAL SECTION through pump at center of eccentric shaft shows places where welding was used in construction. The main end and connecting rod bearings are heavy duty tapered-roller type designed for combination radial and thrust loads. These bearings are preloaded to reduce the shock resulting from load reversals.

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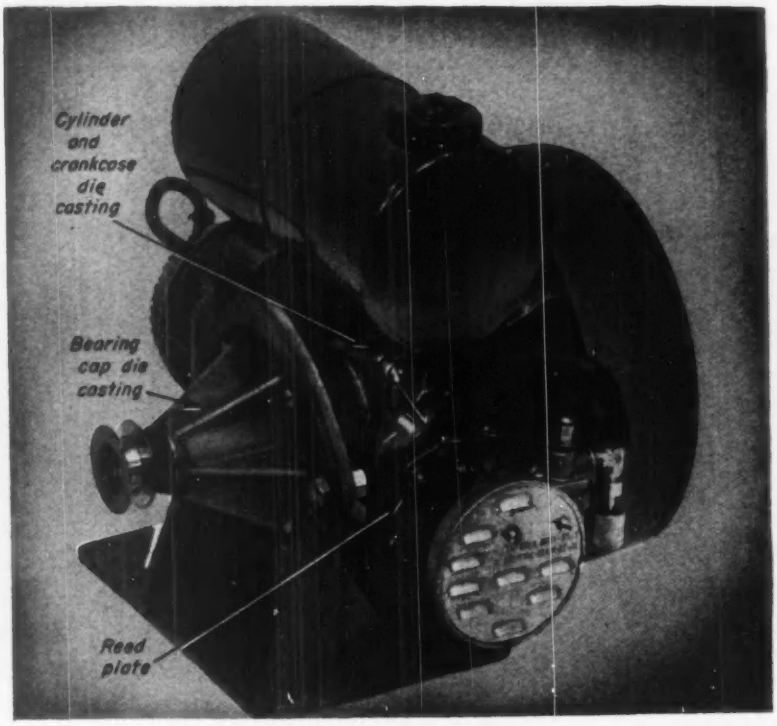
Lightweight Engine Of Die Cast Aluminum

To achieve an objective of maximum power and flexibility with a minimum number of parts and lowest possible weight, the 2-cycle engine developed by the West Bend Aluminum Co., of West Bend, Wis., incorporates a one piece cylinder, cylinder head and crankcase die casting. The dies for this casting have an interchangeable core so that it can be supplied with a lower main bearing for horizontal as well as vertical application.

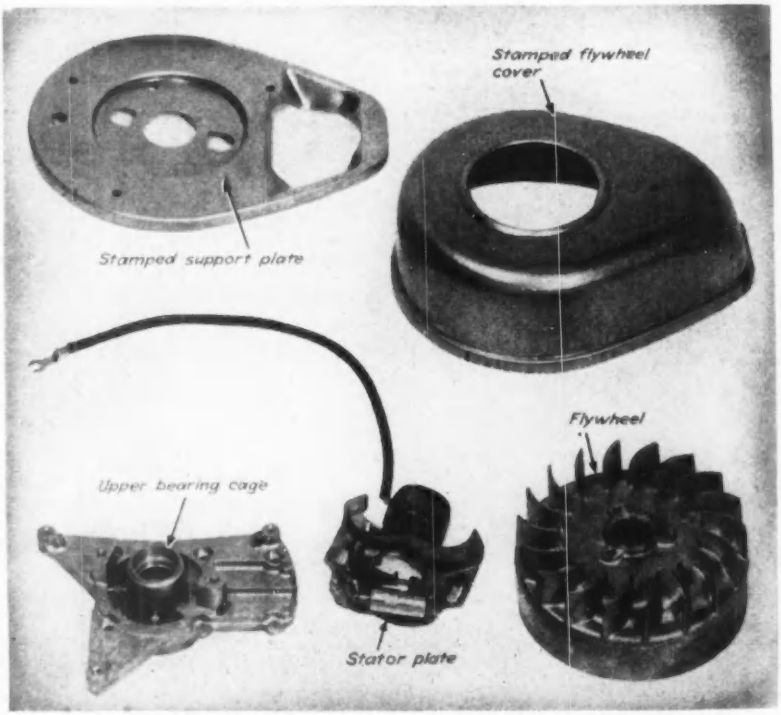
Through the use of aluminum die castings and stampings for all suitable parts, the weight of the basic engine is held down to 15 lb. It develops a maximum output of 1.85 hp at 4,000 rpm.

Additional bosses have been cast on the reed plate or bottom cover plate of the crankcase to accommodate level mounting of the carburetor for either a vertical or horizontal engine. Several versions of two types of carburetors are available with the West Bend engine but the standard model is a conventional bowl design carburetor adapted for use with the air vane-type governor and a filter bowl. Continuous operation in extremely tilted position (up to 45 deg) is possible with the concentric bowl type carburetor. Either a deep or abbreviated filter bowl design with a bowl drain is also available.

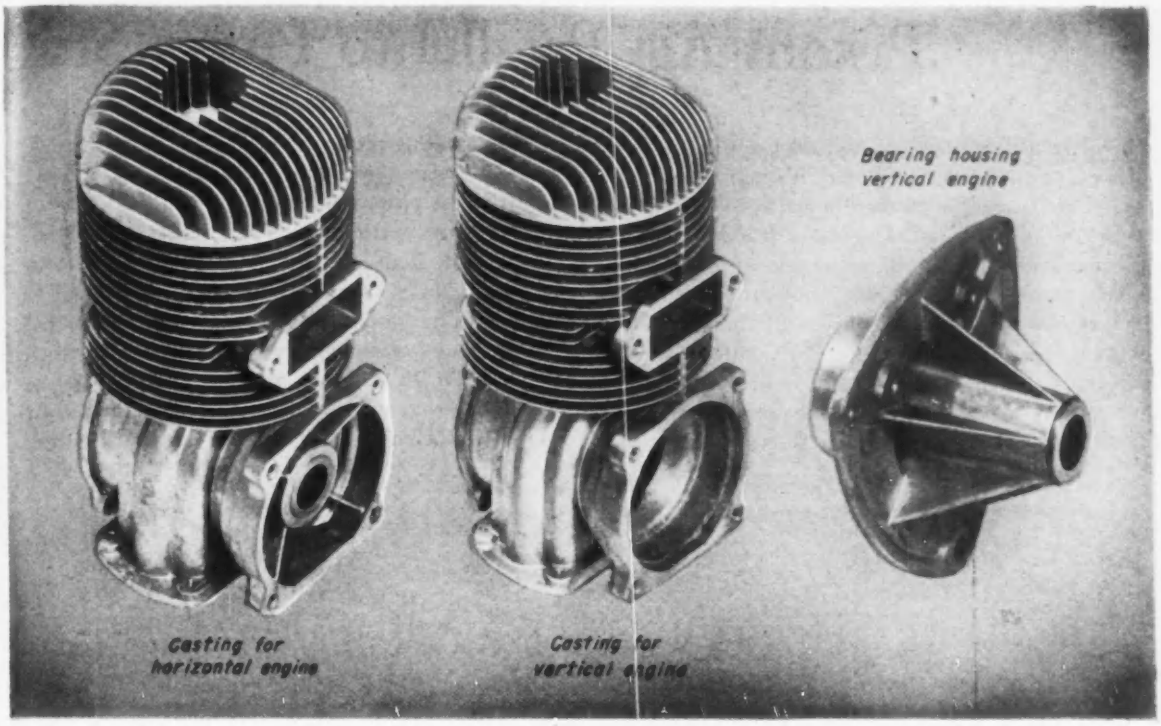
The ignition system uses a high tension flywheel magneto and a standard automotive type spark plug. The engine has a manual rope starter and oil mixed with the fuel provides the lubrication.



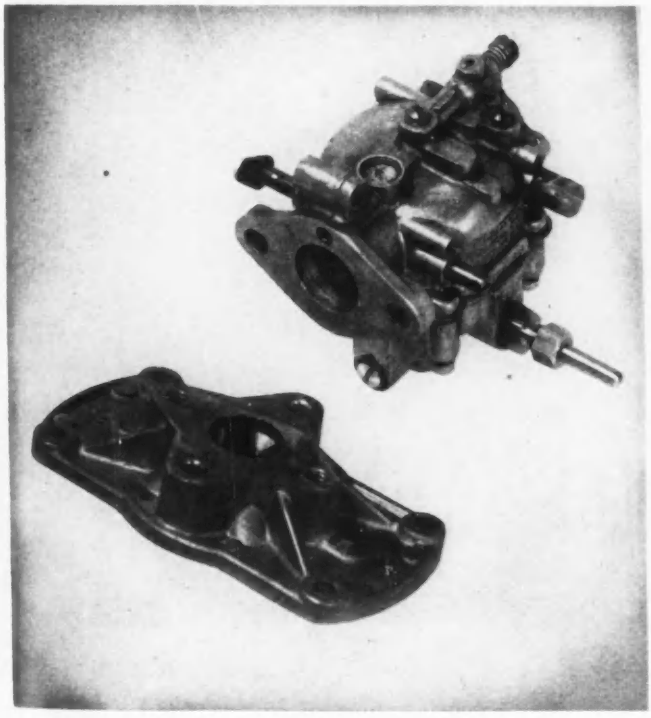
HORIZONTAL VERSION of lightweight aluminum engine. The simplified design makes assembly and dis-assembly of all critical parts easy and the problem alignment is improved by use of the one-piece cylinder-crankcase casting.



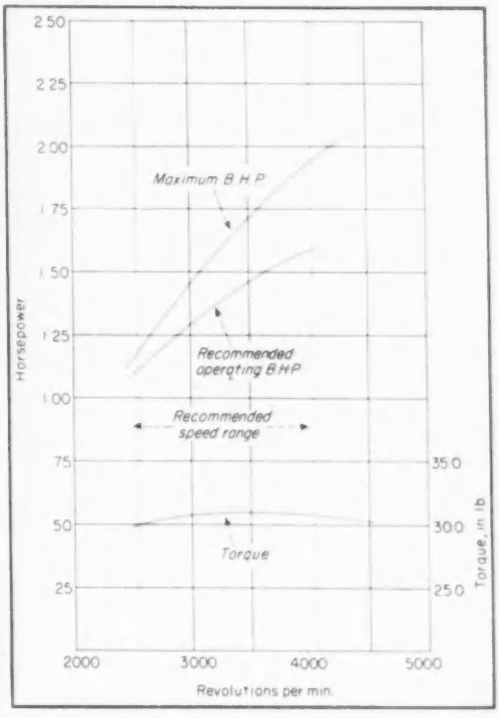
TYPICAL ALUMINUM PARTS used in the engine to help reduce its weight. Aluminum stampings as well as die castings are used. These parts are for an engine with a fixed spark application, but they are typical of all the engines.



TWO CASTINGS of the cylinder-crankcase unit made in the same die. Interchangeable core in the die permits economic manufacture of cylinder casting with different main bearing designs. The bearing housing is an aluminum alloy die casting designed for use in a vertical application. Anti-friction bearings can be adapted to this casting.



DESIGN of the reed plate makes the same part adaptable to either the horizontal or vertical engine applications. Extra bosses on the reed plate permit optional mounting of the carburetor.



PERFORMANCE CURVE of aluminum engine. Although the engine weighs 15 lb, it develops a maximum horsepower of 1.83 at 4,000 rpm.

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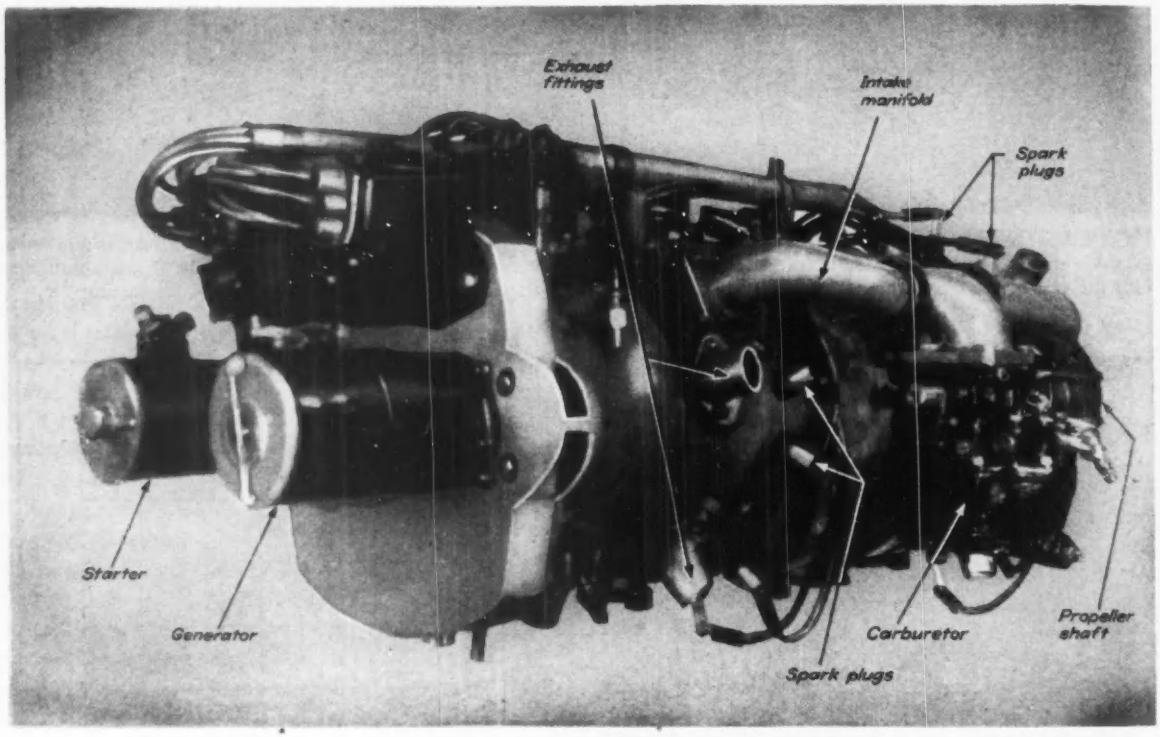
Pistons Act Parallel to Power Shaft

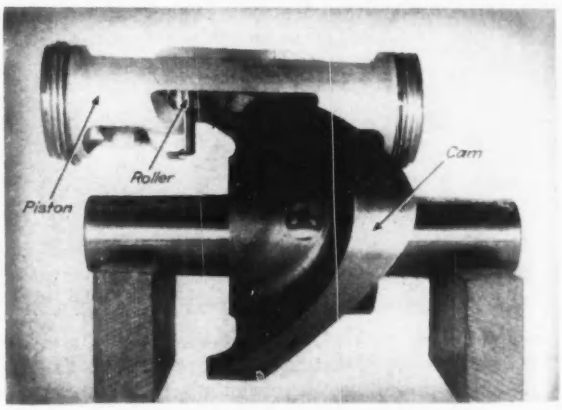
One of the reasons for the relatively large frontal area of a conventional reciprocating internal combustion engine is that the pistons must be arranged to act in lines radial to the crankshaft. The size of frontal the area on conventional engines is of great concern to aircraft designers because it interferes with good streamlined design.

A reciprocating type aircraft engine has been developed by the Herrmann Engineering Company of Glendale, California in which the actions line of the pistons are parallel to the propeller shaft instead of perpendicular to it. Here overall engine diameter is kept small without limiting piston stroke and causing a sacrifice in power. A plate cam on the propeller shaft converts the thrust of the pistons to rotary power.

This design permitted several desirable qualities to be included. Both ends of the pistons are now available to receive thrust from expanding fuel gases and with the propeller shaft passing through the cylinder heads the mechanics of timing the intake and exhaust valve action has been greatly simplified. These advantages have been exploited to produce a relatively simple, light and powerful engine, that suits usual aircraft needs.

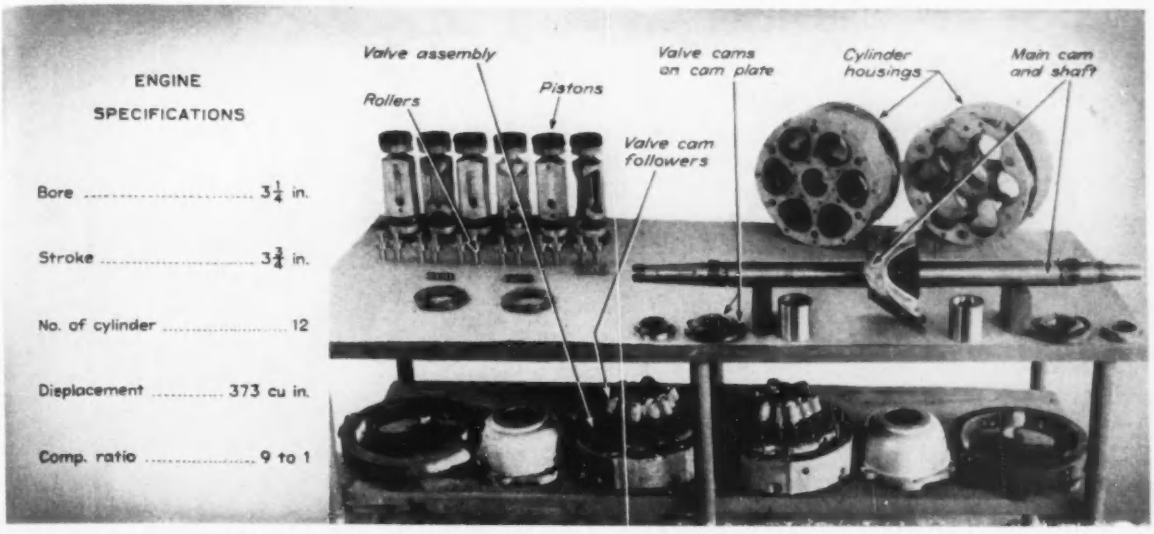


REAR VIEW of 12 cylinder cam engine showing accessory, case ignition system and fuel system. The diameter of the engine has been kept small in proportion to the engine output by providing pistons which act in cylinders parallel to the propeller shaft. Engine develops 180 to 200 hp at 1,800 rpm and weighs 286 lb as shown. Cylinder block assembly is 12¾ in. in diameter and is 49 in. long.

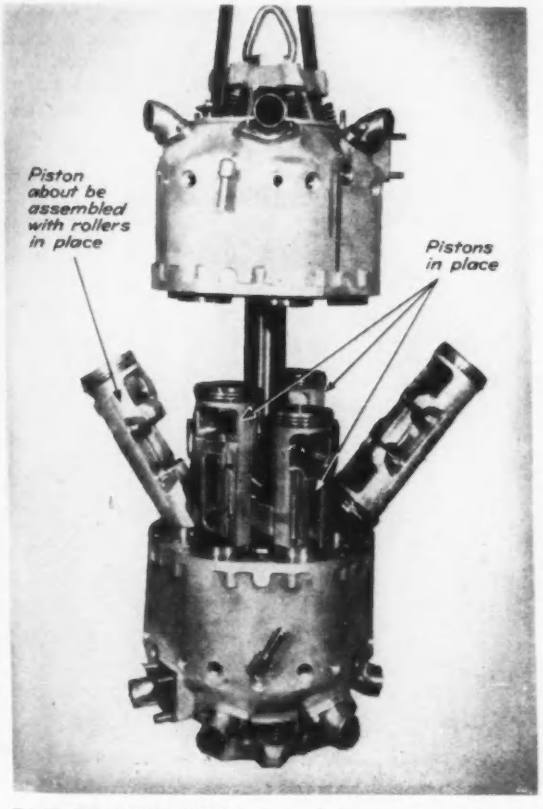


AXIAL THRUST from the double acting pistons is converted to rotary power by a main cam on the propeller shaft in the center of the engine. One of the six pistons is shown in correct relative position with the cam and one of its two rollers, which transmits the sine-wave motion from the piston to the cam, is visible in place.

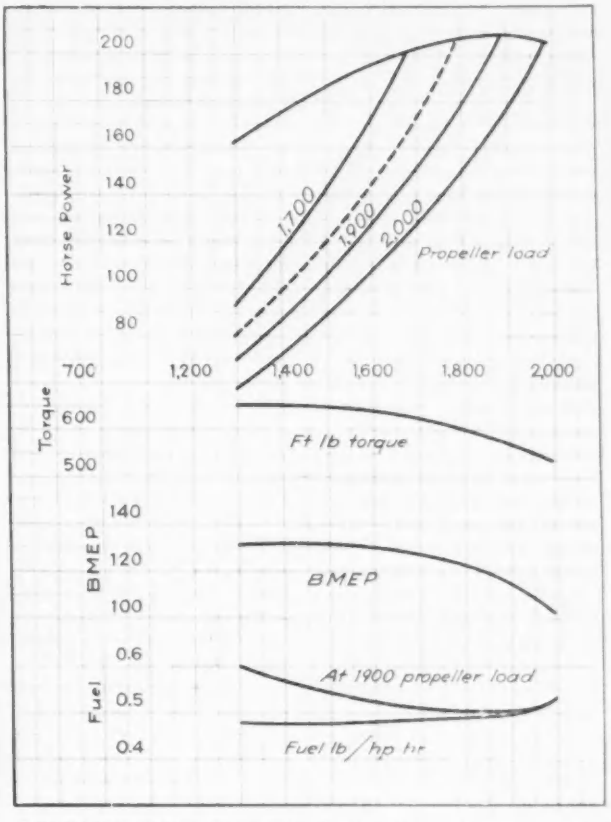
in Internal Combustion Engine



DISPLAY of disassembled cam engine shows the relatively few number of parts it uses to produce 200 hp. The cam plates are keyed to the shaft and control valve position through the roller type cam followers on the valve stems.



EASE OF ASSEMBLY is one of the cam engines good qualities. To install the pistons insert the cam followers, position the main cam and set the pistons in place.



PERFORMANCE CURVES of the Herrmann cam engine. Aviation fuel of 80 octane rating was used in the tests from which these power and fuel consumption curves were drawn.

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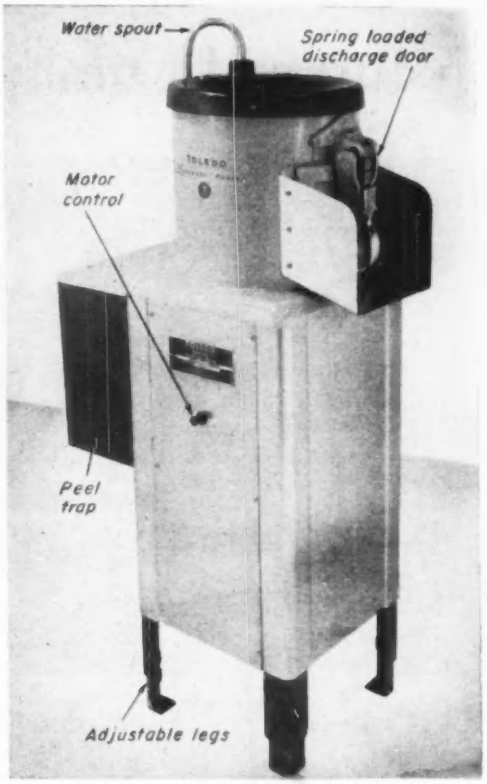
Carborundum Abrasive Peels Vegetables

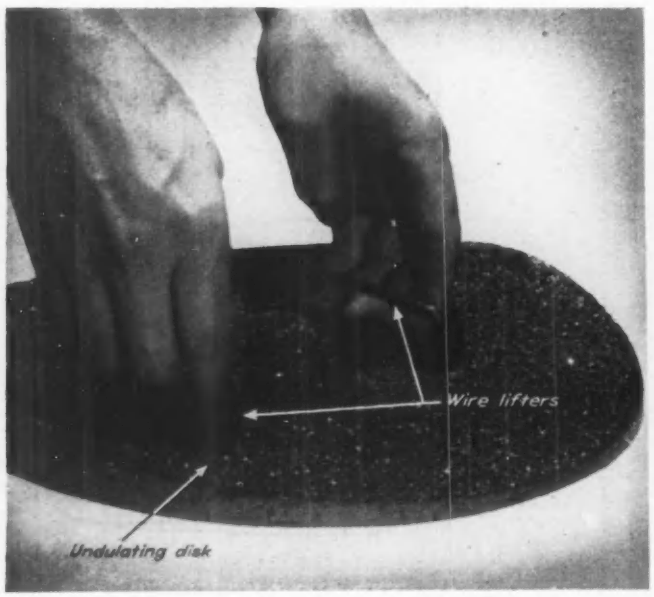
An unusual application of Carborundum abrasive material is being made in a line of vegetable peelers manufactured by Toledo Scale Company, Toledo, Ohio. The peeler operates by tumbling and rolling the vegetables around the Carborundum coated inside surface of a cylinder, at the bottom of which is a rotating disk with a wavy abrasive coated upper surface. This disk agitates the work and causes the peelings to be removed by scraping them against the sides of the cylinder. The compound movement produced by the rotating wavy disk ultimately brings each vegetable to the abrasive surface where it is cleaned and peelings are carried away to a trap by a stream of water that flows over the vegetables constantly during cleaning operations.

The abrasive material is said to last about 3.5 years under normal operating conditions. When the abrasive on the steel cylinders becomes ineffective the cylinders must be replaced since steel cannot economically be rebonded. However the cast iron cylinders and undulating disks can readily be resurfaced.

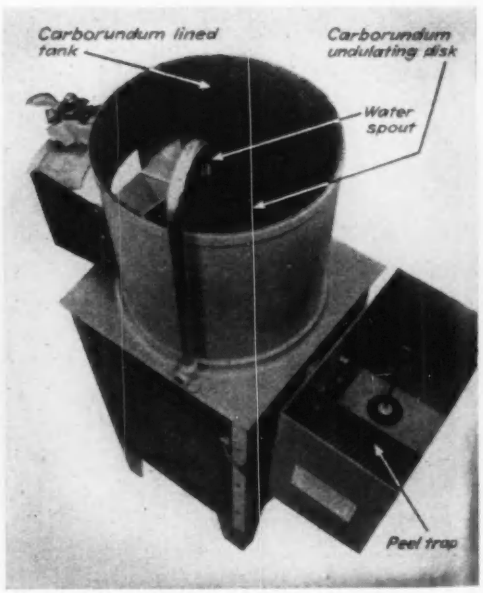
Since the undulating disk must have a strong positive drive and still be removable for cleaning purposes, it rides on a tapered square post in the bottom of the cylinder. The discharge door is mounted on a spring loaded hinge that supports it against the centrifugal forces of a whirling load of vegetables during the peeling operation or will hold the door open for unloading.



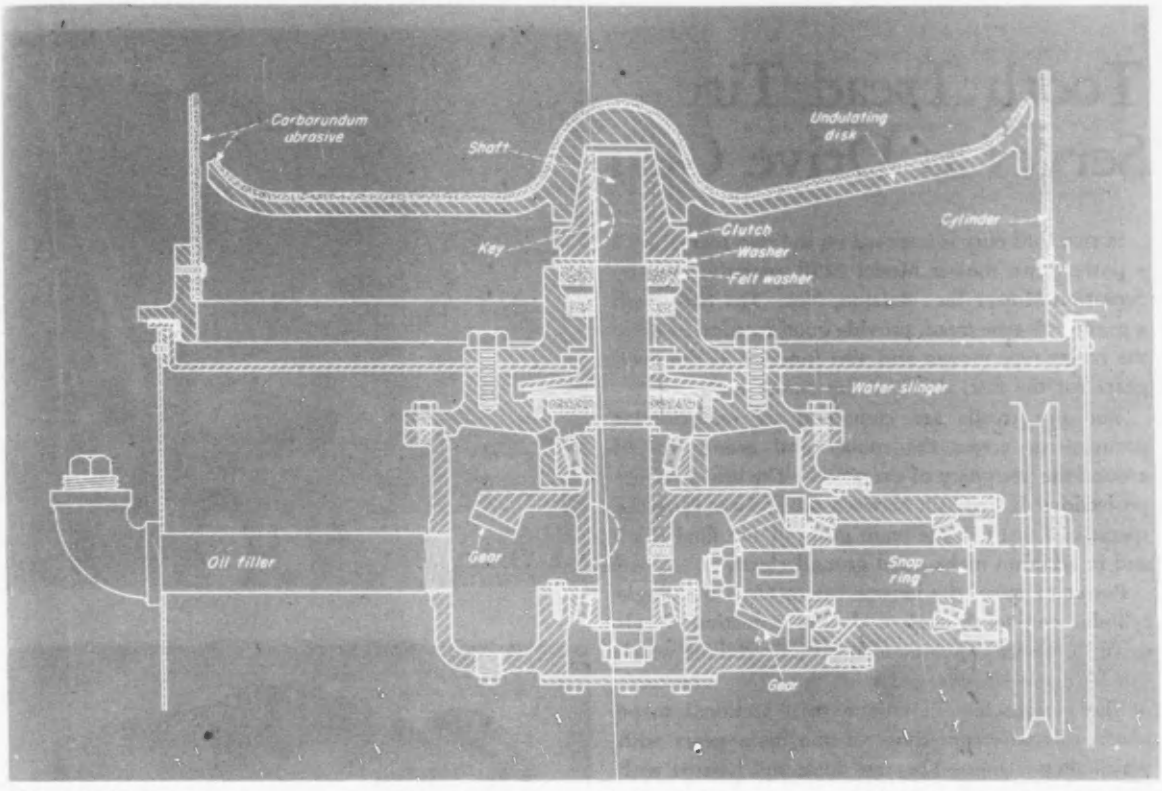
THE PEELER is charged with vegetables to be peeled at the top of the cylinder and cleaned vegetables are taken out at discharge door. The machine is controlled manually. The model A-1-30 will clean 30 lbs of material in 1 to 1¼ minutes.



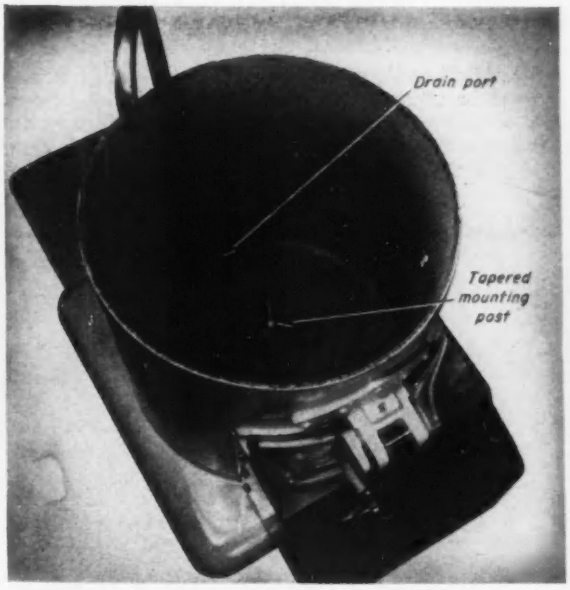
THE UNDULATING DISK is equipped with two loose wire holders that can be used to lift it from the peeler. Here is evident the undulating or waved surface of the rotating disk, that agitates the vegetables and brings them to the abrasive surface to be cleaned.



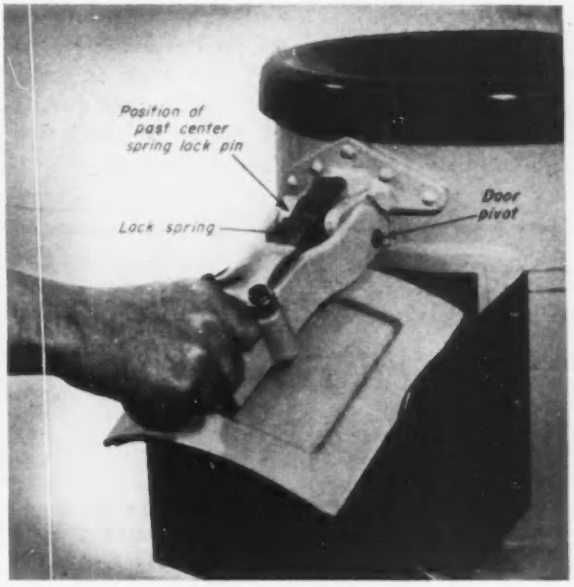
CARBORUNDUM LINED WALLS of the cylinder and carborundum coated surface of the undulating disk in the bottom of the cylinder remove the skins from the vegetables in process.



SECTIONAL VIEW of power train and gear box shows how undulating disk is mounted to its shaft. The tapered clutch affords positive driving and permits easy removal of the undulating disk. Power to drive the peeler comes from a manually controlled electric motor in the base of the cabinet, through a V-belt drive to the bevel gear train. Tapered roller bearings are used throughout to maintain rigid shaft support and shaft seals are used to protect the gear box from water and dirt. The gear unit holds approximately one quart of SAE 90 oil.



A TAPERED POST of square cross-section provides a drive for the undulating disk from which the disk can easily be removed. With the disk removed, the drain port that carries away the peeling is exposed.



THE PAST-CENTER SPRING LOCK on the discharge door will hold the door firmly in full open position or will hold it tightly against the discharge port. A neophrene gasket on the inside edge of the door serves as a seal.

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Tooth Tread Tire Serves as Drive Gear

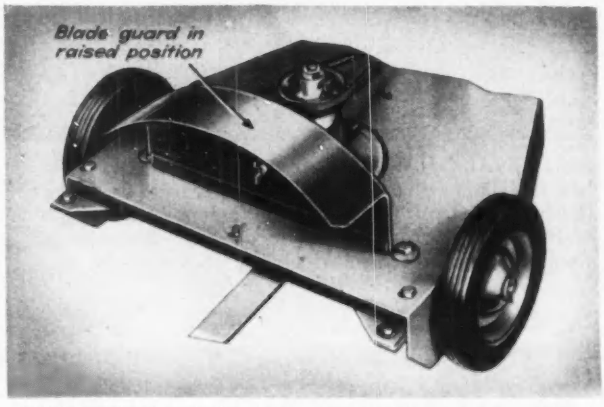
A two fold duty is imposed on the two rear tires of a power lawn mower Model 22SP, manufactured by Sensation Mower Inc., Ralston, Neb. The tires, with a gear tooth type tread, provide good traction to drive the rotary type mower and also function as the main gears for the final drive of the power train.

The tire treads are composed of semi-circular grooves cut across the rubber and evenly spaced around the periphery of the wheel. The broad rubber projections that remain between the grooves form the specialized teeth in the main gears of the final drive and in addition make good ground cleats.

Power to move the mower comes from the single cylinder engine through a double reduction V-belt drive to the two aluminum four-tooth pinions which can be manually engaged with the tires. The teeth of the pinions have a unique cross sectional shape much different from those of the main gears with which they engage. They are long and narrow with ample clearance in the spaces between them to permit trapped foreign material to escape. A gear tooth formed in this manner has a very unusual contour but in a unique application such as this perhaps it serves better than would one of a more conventional design.

The speed of the engine is controlled by hand throttle and an engine governor. The rotary blade is engaged by an automatic centrifugal clutch and can be disengaged by closing the hand throttle.

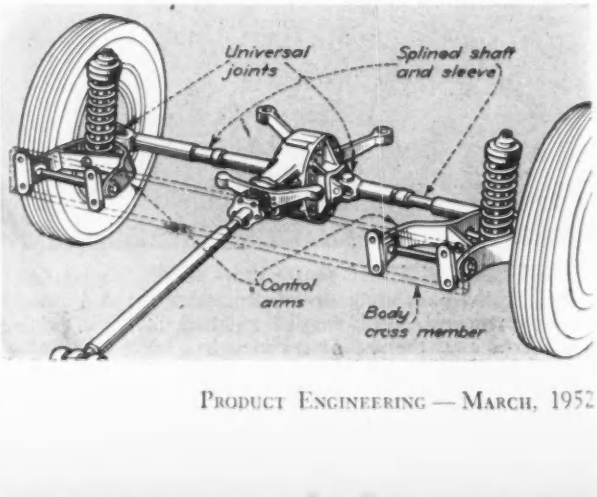
The cutter blade is made of three layers of steel. The outer layers are high carbon steel and the core is low carbon steel. The outer layers keep a keen knife edge and the core gives the blade resilience.

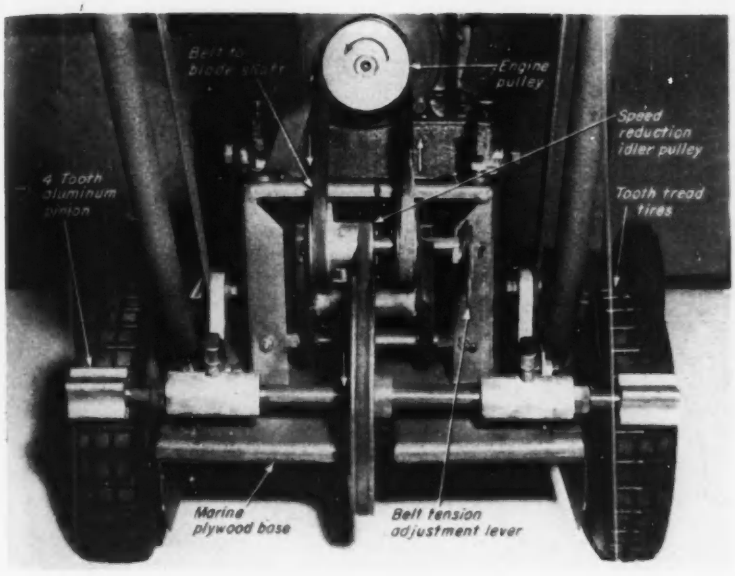


BY FOLDING back the front guard the front section of blade travel can be exposed for mowing brush and high grass or weeds. A snap type lock is provided on the 22SP mower to hold the guard in open position. The front wheels are shown folded back where they offer the greatest stability.

Structural Features of Several Foreign Cars

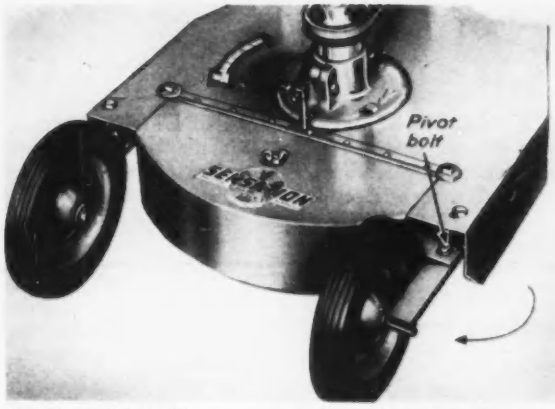
THERE ARE SEVERAL very unique design features to be found in the European cars for 1952. One of the cars with unusual frames is the Skoda 1102, a small car (13 ft 3½ in. long overall) made in Czechoslovakia. The chassis is built up from a single steel tube that extends from the forked front end frame, where the engine assembly, transmission and front suspension system are mounted, to the differential housing on which



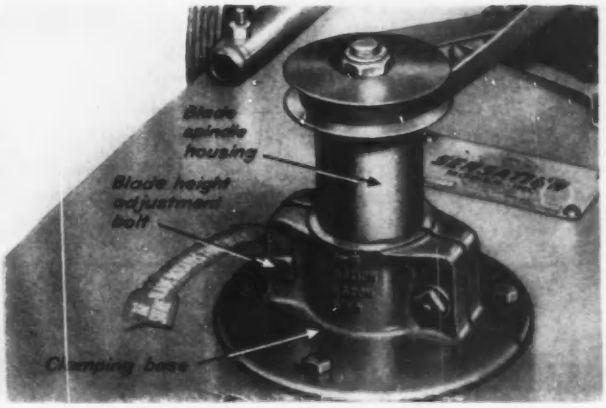


THE CURVED plow type handles are designed to provide a comfortable grip for the operator regardless of his height and the gear engagement bar extends full width of the handle for convenient control. The elevated engine mounting reduces danger of ground dust being sucked into the engine air intake port.

THE FOUR-TOOTH aluminum pinions engage the tooth treaded tires of the rear wheels to drive the lawn mower. The teeth of the gears are specially designed to provide clearance for dirt and grass clipings to escape from between engaging teeth without causing excessive interference. Arrows indicate direction belts travel to turn the wheels and blade.



FRONT WHEELS are mounted on pivot mountings that permit them to be turned from the sides of the mower where they offer maximum stability to the front of the mower. Here distance between them is less than the blade diameter and permits closer grass trimming operations. To



adjust blade height, the clamping base is loosened and the entire blade spindel assembly moved up or down to the desired height of cut. The blade shaft is mounted on Timken tapered roller bearings. Marine plywood is used for the base because it is a good sound deadener.

it is bolted. The rear wheels are independently suspended on the ends of a semi-eliptical spring fastened to the differential housing and flexibility is provided in the axles by universal joints. The propeller shaft goes through the central tube.

The Aston Martin DB II, an English sport car, has a bridge like frame built up from rolled steel tubes of rectangular cross-section. The tubes measure from about 1 in. in height for brace members to about 2 in. for side rails. Most of the bends in the frame are sharp angles and a great deal of cross bracing is used.

The two main members of the chassis in the Mercedes-Benz are eliptical in cross section and pass under the car very close together with only enough room between them to accommodate the propeller shaft. They form the backbone of the car. All cross members are tubular and are welded to the central rails.

The Renault Fregate, a 4-cylinder, six passenger sedan, has independent wheel suspension for all four wheels. The front wheel suspension acts similar to conventional American design with upper and lower control arms to hold the wheels. The rear wheels are mounted separately (left), each to a triangular shaped lower control arm, and these control arms are hinged separately to the ends of a cross-member in the frame. The control arms are supported by coil springs anchored in the body side rails. Universal joints and splined couplings in both the rear axles provide ample flexibility in the final drives.

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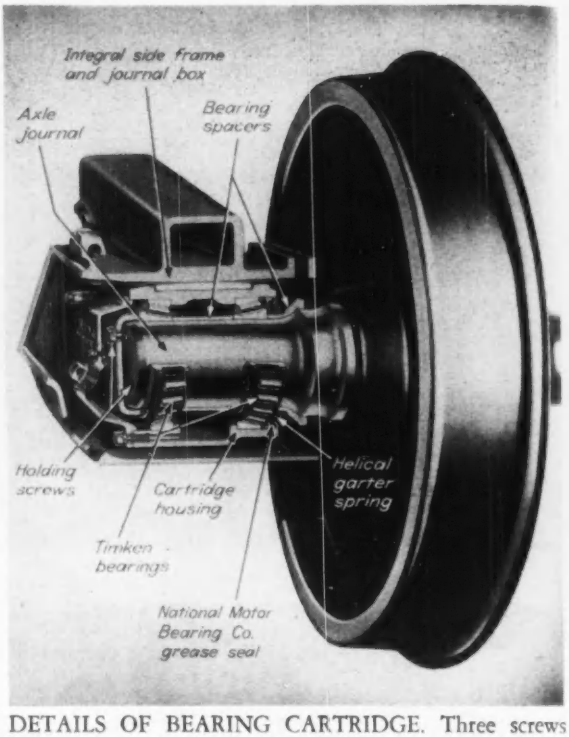
Interchangeable Bearing Cartridge for Freight Cars

An interchangeable roller-bearing cartridge for use on railroad freight car trucks has been developed by the Timken Roller Bearing Company to replace the plain brasses now in common use for the journal bearings. The cartridge is a steel cylinder in which is held two tapered roller bearings that are positioned on the journal by spacers. A bolted on cap covers the outer end of the cartridge and a special grease seal made by the National Motor Bearing Co. keeps the grease in and the dirt out at the wheel end. One application of standard AAR (Association of American Railroads) grease is expected to lubricate the unit for 36 months.

This same roller-bearing cartridge journal box assembly will fit any of the three freight car truck side frame designs in common use and will be available in sizes to fit AAR standard axles. The use of roller bearings on freight cars will permit longer trains because of the lower starting friction, and thereby pay for themselves.

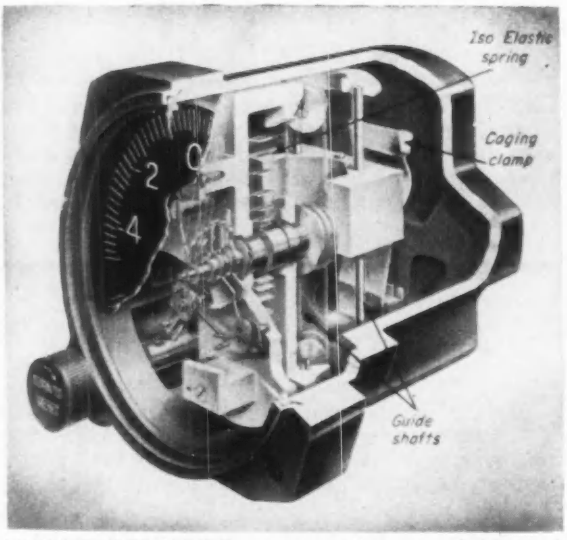


DETAILS OF BEARING CARTRIDGE. Three screws hold the cartridge to the shaft and the spacers locate the 2 tapered roller bearings. The spacer next to the wheel permits turning a large fillet on the journal.

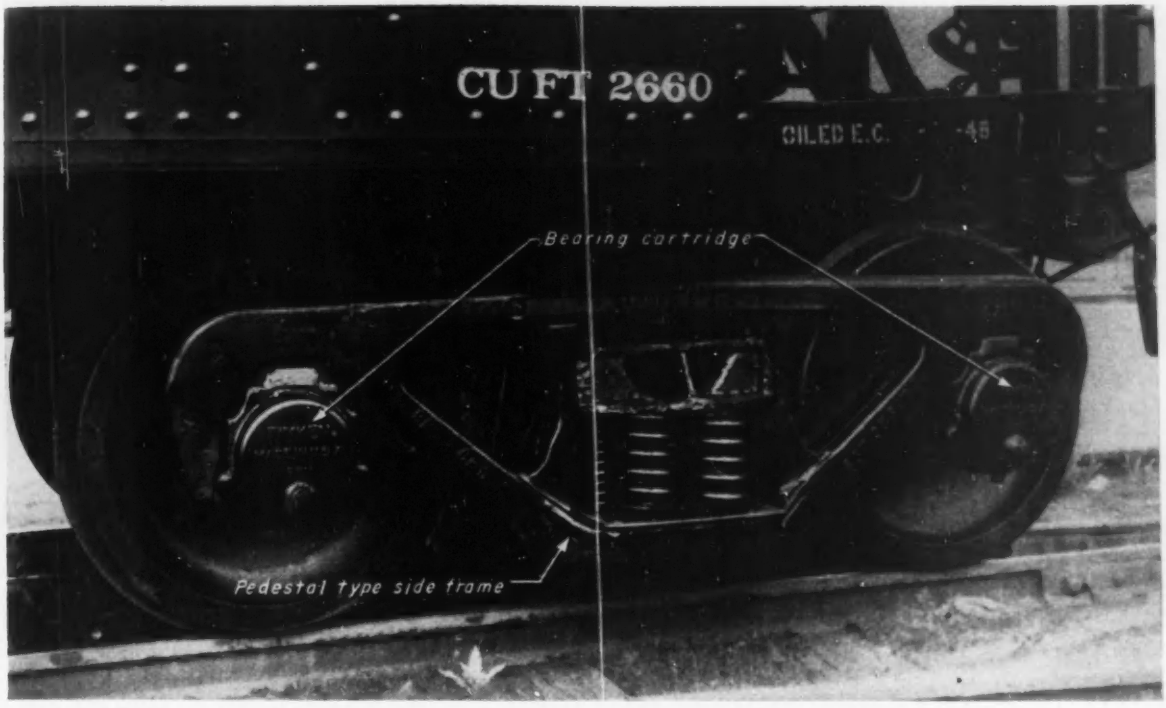
Temperature Compensated Spring

The main spring of the Eclipse-Pioneer aircraft accelerometer maintains accurate instrument readings over a temperature range of —55 to +70C. The spring is made of a special nickel alloy and has a temperature coefficient of modulus of elasticity approximately one tenth that of spring steel. In earlier accelerometers, where steel springs were used, error in indications at high temperatures required the use of cumbersome temperature-compensating mechanisms. With Iso Elastic springs the compensators are not necessary.

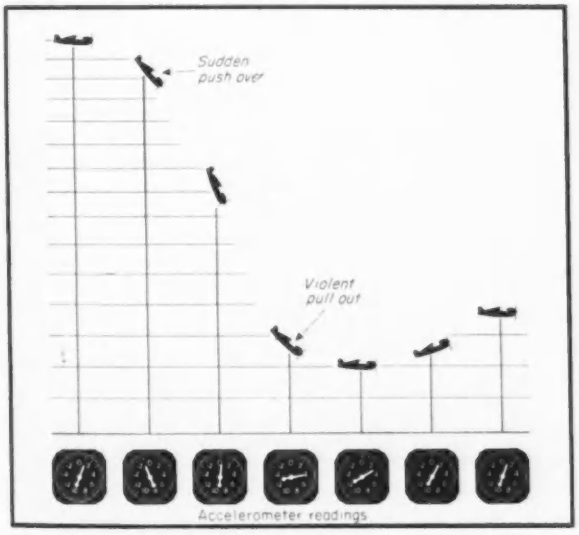
Hysteresis error in Iso Elastic springs is less than 0.05 percent of the spring's deflection. The springs have excellent straight line load versus deflection characteristics. The creep does not exceed 0.02 percent of the deflection of the spring and this takes place within a few minutes after the spring is installed, whereas steel springs or springs made of nonferrous material creep over a more extended period of time.



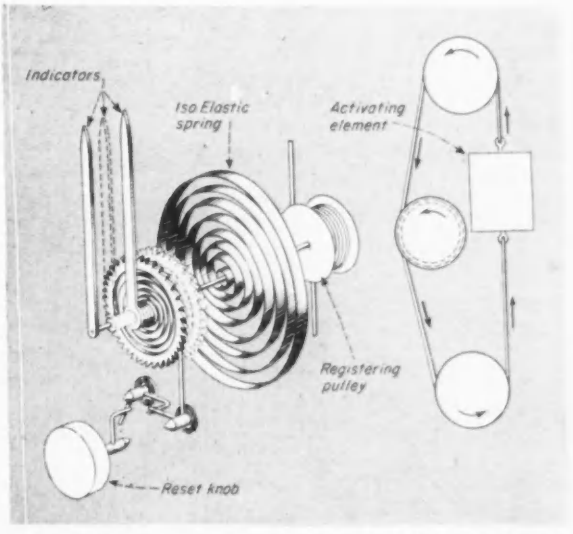
THE TEMPERATURE compensated spring of this accelerometer is made of a special nickel alloy produced by John Chatillon & Sons of New York City. The nominal composition of the alloy is 36 percent nickel, 7 percent chromium, 0.5 percent molybdenum and the balance is principally iron. With these springs, it is claimed that accuracy can be maintained at temperatures from —55 to +70 C. Their constant spring rates simplify design.



RAILROAD FREIGHT CAR equipment with proposed journal bearing cartridges. The cartridge is designed to fit any of the three standard ARR side frame designs in common use. Broken axles and journal box fires are two main causes for railroad freight car bearing failure. A study conducted by Oscar J. Hagar of Timken Roller Bearing Company showed use of roller bearings will greatly reduce accidents where bearing failure is the cause.



INDICATIONS provided by the instrument are used by the pilot in keeping the maneuvering loads imposed on the airplane from exceeding the design load factors of the airplane structure. This illustration shows the approximate variation in reading with the changes in the direction of flight. The instrument will read directly in gravitational load factors for both positive or negative loads. Many military airplanes will stand more than a 10 G load.



The accelerometer operates on the principle that bodies in motion tend to remain in motion, and bodies at rest tend to remain at rest. The activating element in the instrument is a mass which moves on a pair of shafts in a vertical direction. The vertical motion of the mass is transmitted through the shaft and pointers by a spring and pulley system, and the vertical movement of the mass is restrained by the temperature compensated Iso Elastic spiral spring.

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Selecting Hard Facing Materials

HOWARD S. AVERY
Research Metallurgist
American Brake Shoe Company

Table I — Classification of Hard Facing Alloys by Chemical Composition

AWS CLASS	DESCRIPTION	CARBON, percent	CHROMIUM, percent	OTHER ELEMENTS, percent
I	Ferrous Alloys			
IA	Hardenable Alloys			
I-A-1-	Carbon Steels	0.19 max.		See AWS Spec. A5.1-48T
a.	Low	0.20-0.60		1 maximum
b.	Medium	0.61 min.		1 maximum
c.	High			
I-A-2-	Low Alloy Grades	0.19 max.		See AWS Spec. A5.5-48T
a.	Low Carbon	0.20-0.60		0.4-6.0
b.	Medium Carbon	0.61-1.50		0.4-6.0
c.	High Carbon	1.50 min.		0.4-6.0
d.	Cast Iron Types			
I-A-3-	Medium Alloy Grades			
a.	Medium Carbon	0.21-0.60	4-10	6-12 including chromium
b.	High Carbon	0.61-1.70	4-10	6-12 including chromium
c.	Cast Iron Types	1.70 min.	4-10	6-12 including chromium
I-A-4-	High Alloy Grades			
a.	Low Carbon	0.20 max.	10-14	12-30 including chromium
b.	Medium Carbon	0.21-0.50	10-14	12-30 including chromium
c.	High Carbon	0.51-2.5	10-14	12-30 including chromium
d.	Cast Iron Types	2.50 min.	10-14	12-30 including chromium
I-A-5-	High Speed Steels	0.61 min.	2-6	Tungsten and/or Mo
IB	Austenitic Steels			
I-B-1-	Chromium & Cr-Ni Grades			See AWS Spec. A5.4-48T
a.	Low Carbon			4 maximum
b.	High Carbon, low nickel	0.20-1.70	4.0 min.	4 maximum; except
c.	High Carbon, high nickel	0.20-1.70	15.0 min.	for 7.0-Ni min.
I-B-2-	High Manganese			Min. of 3.5Ni and 12.0Mn
a.	Nickel-manganese type	0.70 min.		Min. of 1.0Mo and 11.06Mn
b.	Moly-manganese type	0.60 min.		
IC	Austenitic Irons—not usually heat treated.			
I-C-1-	High Chromium Iron	2.0 min.	22.0 min.	
I-C-2-	High Alloy Irons			6-12 including chromium
a.	Medium Carbon	1.7 min.	4-10	12-30 including chromium
b.	High Carbon	2.5 min.	10-14	Minimum of 40 iron
c.	Very high alloy	2.5 min.		
IIA	Cobalt Base-medium carbon		24.0 min.	40Co min. 3.5W min.
IIB	Cobalt Base-high carbon		24.0 min.	40Co min. 10.0W min.
IIIA	Tungsten Carbide Inserts			
IIIB	Composite Tungsten Carbide	1.8 min.		
IIIC	Tungsten Carbide Powder			
IVA	Copper-zinc alloys (brasses)			85Cu min.-5.0Si max.
IVB	Copper-silicon bronzes			80Cu min.-8.0Al min.
IVC	Copper-aluminum bronzes			2-30Ni, 70-98Cu
VA	Nickel-copper Alloys			
VB	Nickel-chromium alloys			
VC	Nickel base, Cr-W-Mo alloys			

TODAY HARD FACING is being used by both job shops and high production plants for the manufacture of new equipment because: (1) highly alloyed metal can be applied directly to focal areas of wear; (2) readily fabricated and machined materials, such as low or medium carbon steels, can be used as the base metal; (3) a combination of structural toughness and surface hardness that would otherwise be difficult to get can be obtained; (4) lesser amounts of high cost scarce alloys are required; and (5) the process provides protection in depth as compared to carburizing or electroplating.

The type of hard facing alloy that should be selected, Tables I and II, depends on whether wear will be caused by impact, heat, friction, or abrasion, or a combination of these factors. Accurate analysis of conditions that occur in service is difficult, but consideration and study of the factors producing wear will at least provide a basis for selection.

Important Types of Wear

Mechanical wear is the result of stress. Complexity arises from the many ways in which stress is applied and distributed. If the stresses are applied through hard particles, usually of a foreign and non-metallic material, the wear is typed as erosion or abrasion; if the stress arises from collapsing bubbles in a turbulent fluid it may produce cavitation erosion; if from the interference of metal surfaces in motion, it can be called frictional. Stress, by forcing clean surfaces into intimate contact, may also cause sei-

to Resist...

Impact
Heat
Friction
Abrasion

zure, galling, scuffing or scoring, and these phenomena, typed as welding wear, are usually associated with friction under conditions of poor or incomplete lubrication.

IMPACT. The severity of impact and the ability of the base metal to withstand deformation are usually the first factors to be analyzed in selecting a hard facing alloy. This should lead to a decision, guided by Tables II and III, as to whether austenitic steels, air hardening types, or the brittle but more abrasive resistant grades are to be employed.

If the energy can be absorbed and then returned by fully elastic behavior, no structural damage results and materials can be selected that will have the necessary elastic strength—provided the velocity is not too high. The relatively light but repetitive impact blows experienced by machine parts such as tappets and cams are examples. Martensitic irons and steels can provide good protection for these parts, Fig. 1, apparently because of their high compression strength.

Beyond a critical velocity or under high energy blows it is not possible to avoid plastic deformation. Failure may be induced as cracks develop from excessive deformation. Ductility becomes an asset in this case. Austenitic manganese steel has an optimum combination of strength and ductility and exceptional resistance to crack propagation. However, it has a low yield strength and will batter down more rapidly than harder steels. Some martensitic steels have good intermediate properties and can serve well in the field between light and heavy impact.

Impact stresses may be transmitted through a competent hard overlay and cause deformation of the underlying base. This can lead to residual tensile stresses on the underside of the overlay. If base deformation is progressive, cracking of the overlay will result. The solution is the selection of a stronger base metal or more ductile overlay material.

Need for abrasion resistance combined with tensile impact resistance usually forces a compromise on the engineer. One measure of tensile toughness is the product of ultimate tensile strength and elongation. These indices of toughness are plotted against resistance to grinding abrasion in Fig. 2, to illustrate the status of a group of engineering alloys roughly paralleling the classification in Table II. The relatively good combination of properties exhibited by the austenitic man-

Table II – Graded Series of Wear Resistant Alloys

Property*	MATERIAL	CHARACTERISTICS*
Increasing Abrasion Resistance ↑	1. Tungsten Carbide Composites	Maximum abrasion resistance Worn surfaces become rough
	2. High Chromium Irons	Excellent erosion resistance Oxidation resistance
	3. Martensitic Irons	Excellent abrasion resistance High compressive strength
	4. Cobalt Base Alloys	Oxidation resistance Corrosion resistance Hot strength and creep resistance
	5. Nickel Base Alloys	Corrosion resistance May have oxidation and creep resistance
Increasing Toughness ↓	6. Martensitic Steels	Good combinations of abrasion and impact resistance Good compressive strength
	7. Pearlitic Steels	Inexpensive. Fair abrasion and impact resistance
	8. Austenitic Steels Stainless Steels Manganese Steel	Work hardening Corrosion resistance Maximum toughness with fair abrasion resistance. Good metal to metal wear resistance under impact

*Properties sensitive to carbon content and structure.

Table III – Hard Facing Alloys for Impact Service

PROPERTY AND USE	MATERIAL		
	Martensitic Irons*	Martensitic Steels*	Austenitic Manganese Steel
Suitable for:	Light Impact	Medium Impact	Heavy Impact
Yield strength tensile, psi	60,000–80,000	60,000–80,000	45,000–55,000
Ultimate tensile strength, psi	65,000–90,000 psi	60,000–125,000	100,000–150,000
Tensile elongation, percent	0.01–0.04	0.01–0.10	30–70
Brinell hardness Rockwell hardness	500–750 C48–C65	500–750 C48–C65	160–220 C0–C20
Yield Strength, compressive 0.10 percent set	150,000–285,000	76,000–175,000	45,000–55,000
Ultimate compressive Str, psi	265,000–385,000	180,000–385,000	200,000–310,000
Elastic deformation, percent Plastic deformation, percent Total deformation, percent	0.8–1.4 0.2–5.4 1.2–6.5	0.8–1.5 1.0–22 1.8–23	30–55
Wet Sand Abrasion Factor** Dry Sand Erosion Factor**	0.30–0.50 0.05–0.15	0.65–0.80 0.15–0.55	0.75–0.85 0.55–1.00

*Untempered, corresponding to the usual status of weld deposits.
**Weight loss ratios compared with annealed SAE 1020 steel.

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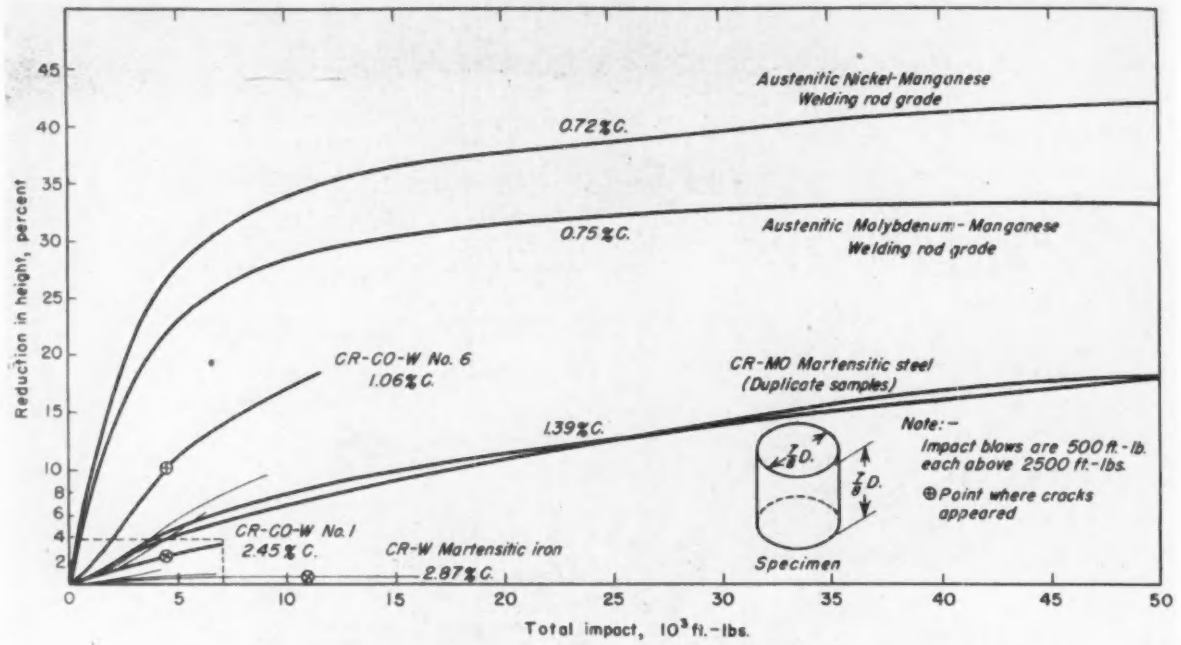

Fig. 1—Effect of repeated impact on hard facing alloys. For repeated light blows, martensitic irons and steels provide good protection because of their high compressive strength.

ganese steels explains why these materials are favored for impact combined with abrasion.

HEAT. The maximum temperatures of service and the duration of load application should next be estimated and the best materials that will also meet the impact requirements examined.

Heat can cause metal deterioration through oxidation, tempering, softening and intergranular corrosion.

(a) Oxidation and scaling at high temperatures are best resisted by alloys containing a minimum of 25 percent chromium. Nickel ordinarily can be substituted for chromium in a 3 to 1 ratio. This will aid the formation of a scale which is protective to 1,800 F, or above if no fluxing agents are involved. The high chromium irons, the cobalt base alloys and the stainless steels with 25 percent or more chromium should be considered first for oxidation resistance.

(b) Tempering effects are minimized by pretempering at or slightly above the service temperature. Extra hardness can be obtained from alloy steels and irons containing chromium, molybdenum, vanadium, and tungsten, which confer secondary hardening properties in the range from 900—1,100 F. High speed steels, used as welding alloys, serve well up to 1,050 or 1,100 F, especially since oxidation is not a serious problem below these temperatures.

(c) Creep or plastic flow becomes an important factor above 1,000 F. Up to 1,200 F martensitic irons may have adequate creep resistance, but at and above 1,200 F the cobalt base hard facing alloys seem to provide the highest hot strength under sustained loads.

If both high hot strength and hot gas corrosion at 1,600 F or higher are required, the field is narrowed to the chrome-cobalt-tungsten alloys. These are likely to become scarce, and while substitutes are becoming available, technical data to assist selection are scanty.

If corrosion is involved, the subject should be studied carefully in other references, since this is perhaps the most complex field of wear resistance.

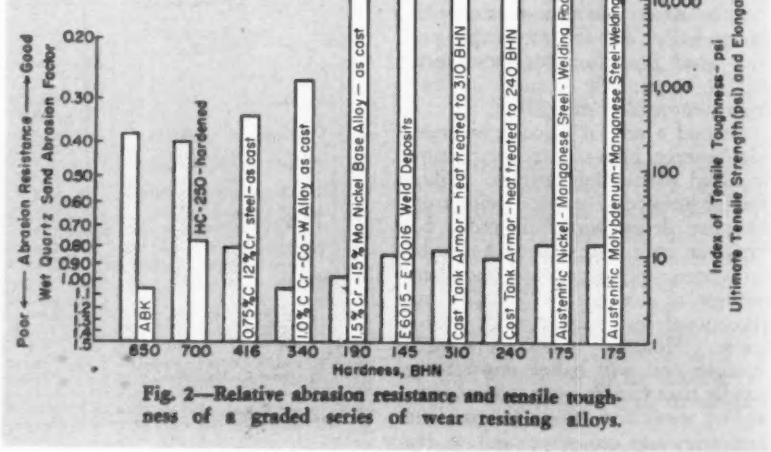
Tensile toughness
Abrasion resistance
Poor ← Abrasion Resistance → Good
Wet Quartz Sand Abrasion Factor
Index of Tensile Toughness - psi
Ultimate Tensile Strength (psi) and Elongation (%)
ABK
HC-250-hardened
0.75%C 12%Cr steel-as cast
1.0%C Cr-Co-W Alloy as cast
1.5%Cr-15%Mo Nickel Base Alloy — as cast
E6015-E10016 Weld Deposits
Cast Tank Armor - heat treated to 310 BHN
Cast Tank Armor - heat treated to 240 BHN
Austenitic Nickel-Manganese Steel-Welding Rod Grade
Austenitic Molybdenum-Manganese Steel-Welding rod grade
650 700 416 340 190 145 310 240 175 175
Hardness, BHN

Fig. 2—Relative abrasion resistance and tensile toughness of a graded series of wear resisting alloys.

Table IV – Properties of Some Martensitic Irons

PROPERTY	CHROME-NICKEL TYPE			CHROME-MOLYBDENUM TYPE			CHROME-TUNGSTEN TYPE		
	Gas Welded	Small Castings*	Arc Welded	Gas Welded	Small Castings*	Arc Welded	Gas Welded	Small Castings*	Arc Welded
Composition, percent		4.5Ni, 1.5Cr.			14.0Cr, 4Mo			18.1Cr, 15W	
Resistance to flow under repeated impact:		Good			Good			Excellent	
Tensile toughness		Low			Low			Low	
Resistance to cracking under repeated impact		Low			Fair			Fair	
Oxidation resistance		Low			Low			Medium	
Maximum temperature considered advisable		1,000 F.			1,100 F.			1,200 F.	
Creep resistance		Low			Fair			Fair	
Rockwell Hardness**									
at 70 F	C60		C64	C63		C57	C62		C65
600 F	C51	C48		C51-54					
800 F	C51	C42		C52					
1000 F	C27	C17	C42	C46-43		C43	C50		C51
1200 F	C–13		C–8	C19-7		C4	C32		C27
Compression strength at 0.10", set Yield—psi		180,000			172-285,000			184-226,000	
Ultimate—psi		260-380,000			310-364,000			292-334,000	
Elastic deformation, percent		0.9-1.6			1.2-1.4			0.9-1.0	
Plastic deformation, percent		0.6-3.0			0.3-1.4			0.1-0.5	
Abrasion resistance	Good	Good	Fair	Excellent	Excellent	Good	Excellent		Good
Wet Sand Abrasion Factor	0.37-0.57	0.30-0.65	0.60-0.74	0.30-0.46	0.34-0.47	0.38-0.54	0.28-0.50		0.40-0.60
Erosion Resistance	Good		Fair	Excellent		Good	Excellent		Good
Tensile Strength, psi	72,000-83,000								
Elongation, percent	0.001-0.050								
Brinell hardness	500-650								

*Properties considered between those of gas and electric weld deposits. Used for some test specimens to eliminate welding variables and defects. **Instantaneous values

FRICTION. While the nominal operating temperature is important, it is also imperative that the momentary high temperatures at friction faces be considered. Unfortunately, such temperatures are difficult to estimate or measure, and the engineer must resort to guesswork. Since the heat developed is likely to be unexpectedly high, it is best to use the alloys, Fig. 3, with good hot hardness characteristics. Below 600-800 F and above 1,200 F the choice is not usually difficult. From 800-1,200 F there is much room for good judgment and critical selection, balancing probable performance against alloy and welding costs. Martensitic irons and steels, Table IV, containing chromium, molybdenum or tungsten can aid here, the choice being narrowed by impact conditions. The damage from friction is attributed largely to welding. Wiping contact removes surface films, dirt, oil and gas layers that prevent metal to metal contact. When clean faces finally touch, they weld together by force of atomic attraction. The smoother the surfaces the greater the area of welding.

Hard facing, by providing high yield strength at the wearing face, can reduce welding wear. Not all wear resistant alloys have high elastic strength, however, and the material must be properly selected. In Fig. 4 are shown the compressive properties of several types.

The welding responsible for seizing and galling can be prevented by oxide films that are thick enough to hold the metallic faces several millionths of an inch apart. Aluminum oxide is such a material. It forms rapidly on aluminum bronze, is tenacious, and if removed is promptly renewed in an oxidizing atmosphere. The aluminum bronze deposition methods employ an inert gas shielded arc or an electrode that contains powerful fluxing agents, since aluminum oxide films also interfere with fusion welding.

Aluminum bronze electrodes, while they do not produce particularly hard deposits, are useful alloys for overlays to work against dissimilar hard alloys and for die protection.

ABRASION. Next, abrasive conditions should be examined and the type of abrasion tentatively identified. If abrasion is obviously the major factor, it may be considered second after evaluation of impact conditions.

It is convenient to subdivide this wear factor into (1) erosion, or

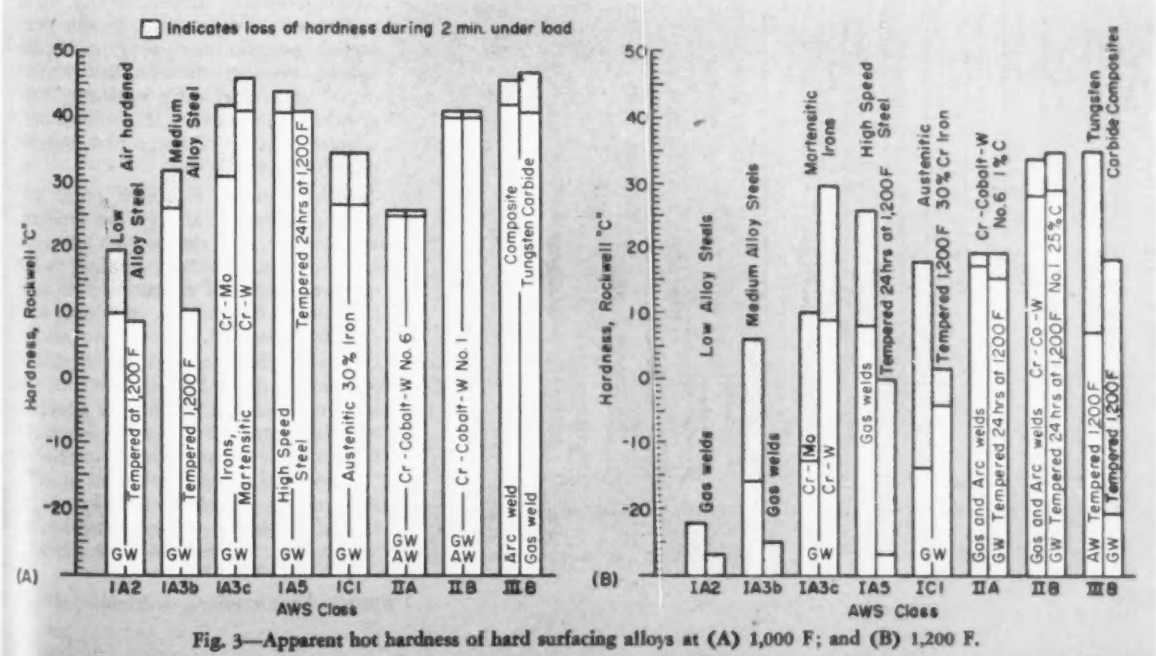

Fig. 3—Apparent hot hardness of hard surfacing alloys at (A) 1,000 F; and (B) 1,200 F.

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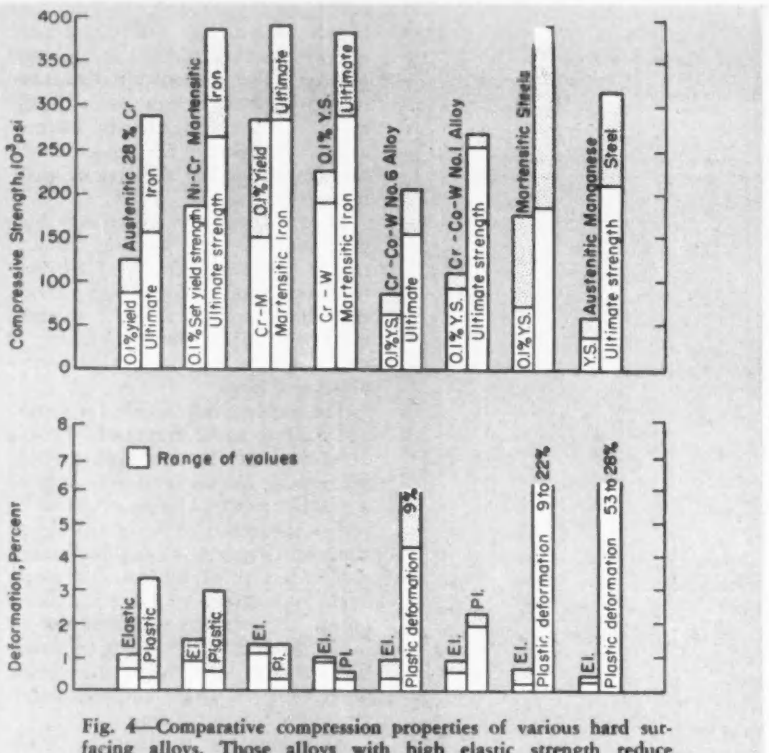


Fig. 4—Comparative compression properties of various hard surfacing alloys. Those alloys with high elastic strength reduce welding wear by providing high yield strength at the wearing face.

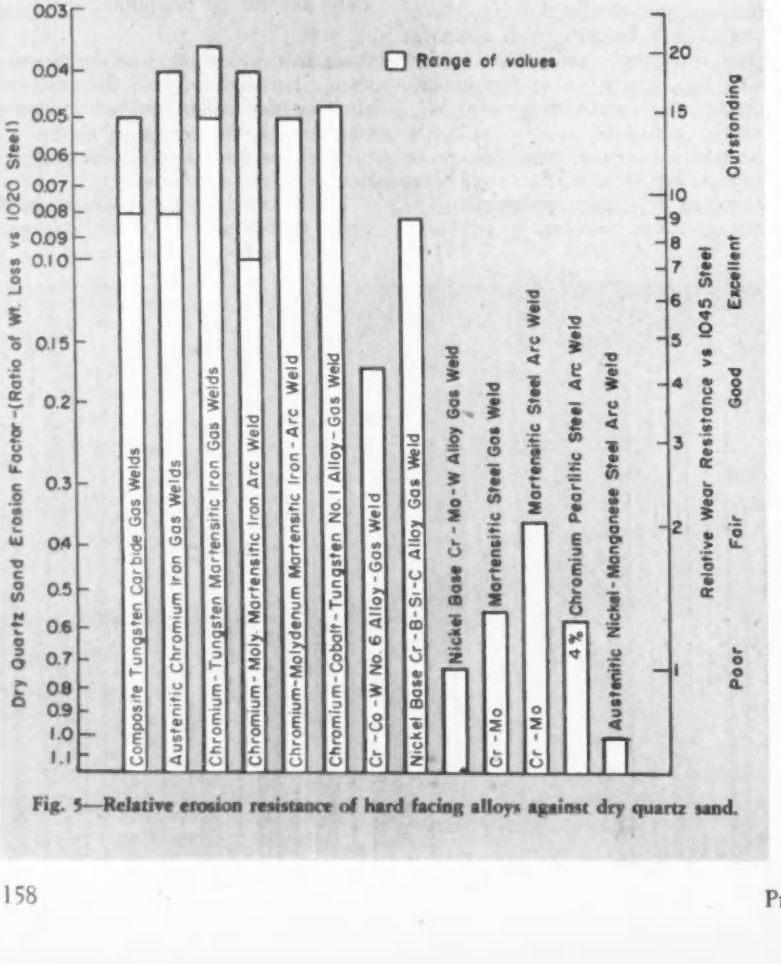


Fig. 5—Relative erosion resistance of hard facing alloys against dry quartz sand.

scratching abrasion, (2) grinding abrasion (which is implied herein when not otherwise designated), and (3) gouging abrasion. The first two are differentiated by the stress that can be brought to bear upon the abraded surface. The third is characterized by anchorage or good support of the cutting agent, much like that for a machine tool cutting bit. These are stated in the order of increasing severity or depth of metal removed per unit time.

While it is possible to obtain good combination properties, the wear resistance of alloys of these three types does not follow a simple pattern. The three must be treated as separate cases in both wear analysis and alloy-selection. The factor of impact frequently complicates them and is particularly likely to accompany gouging abrasion.

Unless tungsten carbide or the chromium-tungsten hard facing in Table IV is selected the engineer should decide whether erosion (Fig 5) or abrasion (Fig 6) is most important. For erosion the austenitic high chromium irons are excellent; for high stress abrasion martensitic iron, especially when gas welded, is a better choice.

These austenitic and martensitic irons polish well, and being less expensive than tungsten carbide they are frequently selected for resistance to abrasion. The choice between them should be based on the identification of erosion versus abrasion (or low versus high stress abrasion). If hot hardness as well as abrasion resistance is required, the chromium-tungsten martensitic iron may be indicated.

Austenitic manganese steel absorbs more energy for a given amount of impact deformation than any other common metal. Independently, field experience has accorded it the preferred position for wear resistance against gouging abrasion that occurs in all sorts of mining, crushing, and grinding equipment. It is, therefore, selected where resistance plus toughness is required.

Unless impact is severe (thus requiring austenitic alloys) the type of surface that may develop in use also may be important. If a polish, with relative absence of roughness and surface teeth, is desirable, the tungsten carbide deposits may not be practical. Otherwise they are best for abrasion resistance. Some latitude in terms of toughness and hot hardness is possible with tungsten carbide by the selection of granule size and welding methods.

In general, gouging abrasion is best resisted by tungsten carbide, high chromium irons are next, and the martensitic irons follow. Were it not

for the associated impact, this trio would be preferred. However, except where they are protected from shock deformation, their brittleness is too great for good life expectancy.

Other Considerations in Selection

Finally, the tentative selection should be reviewed in relations to shut down costs and overhaul schedules, if these are likely to become involved. If life expectancy is obscure, the trial of two or three types, to obtain base line data, should be made for the same installation. The most economical choice will probably be that which lasts just through the normal service interval, or for some multiple of this; there is little advantage in using an alloy that will outwear another by 50 percent, for example, if the base line life is one service period, because the better alloy would need replacement at each overhaul anyway. If life were doubled by 100 percent improvement, however, a real saving can be shown even at considerably greater alloy cost, because replacement need be made only during every other shut-down.

If the logic of an alloy-application combination is not clear, it may be the result of either an exception to the picture presented or of a misapplication. The simplification attempted here has necessarily involved omitting a modest area of hard facing alloys, and a careful scrutiny of an established practice may lead to rewarding changes. Where hard facing has not yet been tried and wear resistance is needed, there is an even greater chance of obtaining improved performance at equal or lower cost per service hours.

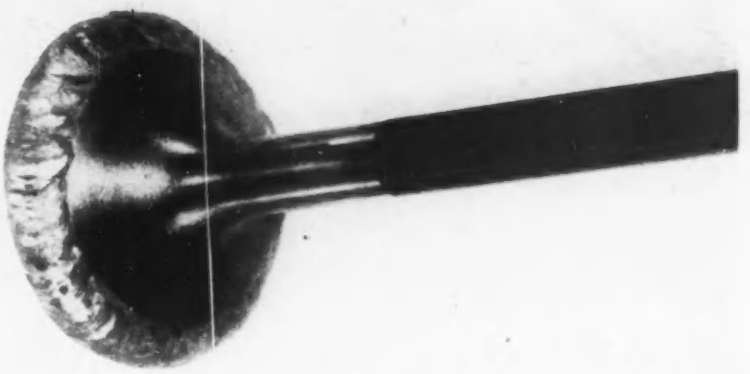
Base Metals for Hard Facing

While most metallic structural materials can be hard faced, the weldability of the base is an important consideration. Deposition upon a base of much lower melting point is likely to be difficult or unsatisfactory. Ordinarily, this is not a problem since most facings are put on iron or steel, the latter generally being best if the engineer has freedom of selection.

A preferred grade is 1045 killed steel, which is relatively strong but fairly free from cracking tendencies. If even greater strength is required, a eutectoid steel with around 0.80 percent carbon can be used, but will require more careful handling. A low carbon mild steel like the 1020 grade may weld easily but often is too weak.

The alloy steels, especially with medium or high carbon content, are difficult to weld without cracking and should be avoided if possible. If they must be welded, a pad of austenitic stainless steel, like 25Cr:20Ni, arc deposited from a lime coated electrode, can help minimize cracking. In any case it will pay to examine the time-temperature-transformation curve for the base steel involved and to control heating and cooling to produce a pearlitic transformation. Carbon steels are unlikely to form martensite unless quenched, but many of the alloy steels, particularly if they pick up carbon during welding, are able to form martensite as the weld cools. Formation of martensite causes expansion and the associated stresses, especially near room temperature, are a common cause of cracks. Hydrogen, already in the steel or picked up during welding, accentuates the cracking tendency.

The base steel should be killed and of good quality since weld defects sometimes are traced to non-metallic impurities or to inadequate deoxidation. The surface should be free of oxides, grease, oil, or other foreign materials. The usual method is to grind the area to be faced.



Cobalt base alloy applied to engine valve to resist hot gas corrosion and impact.

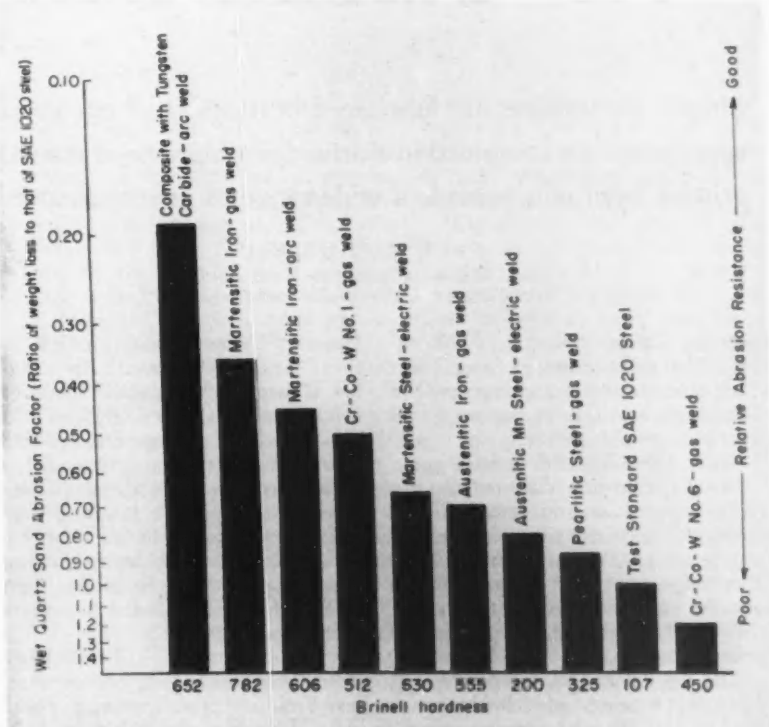


Fig. 6—How the abrasion resistance of various deposits compared when determined by special laboratory test.

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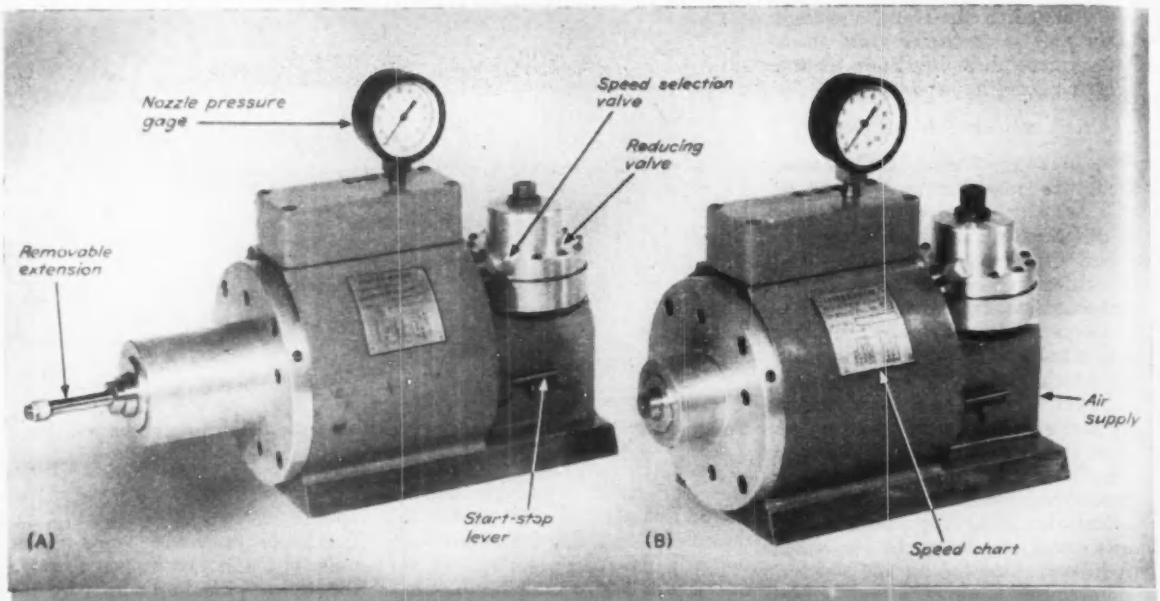

Fig. 1—Air turbine driven spindles for internal grinding machines. (A) This model can be adjusted to hold any selected speed within a 30,000 to 50,000 rpm range. (B) Model having a 60,000 to 100,000 rpm adjustable range of controlled speed.

Air Turbine Driven Spindles

Simple air turbine, air lubricated bearings, and pneumatic speed governor combined in a drive for a high-speed internal grinder head unit provide a wide range of governed speed.

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RECENT DEVELOPMENTS in the design and construction of several turbine driven internal grinding spindles have made available an improved tool for the precise finishing of small holes. These spindles exhibit some new characteristics that reduce the skill required on the extraordinary jobs, such as where the hole must be equivalent to "lapped". In addition, they show somewhat better performance of the usual factors that affect the quality and cost of production grinding.

The specific design incorporates air lubricated bearings and closely regulated control of speed. These bearings and the governor have been discussed in detail in two previous articles; see "Air Lubricated Bearings," PRODUCT ENGINEERING, August 1951, p 112; and "Governors for High Speed Rotating Machinery," PRODUCT ENGINEERING, October 1951, p 170. The integration of these features with a simple air turbine drive and a connection with the usual shop compressed air supply is a fortunate combination that results in:

1. Relatively low installation cost when compared with the familiar high cycle electric heads needed for equivalent speeds.
2. A high percentage of availability and insignificant bearing maintenance.
3. Freedom from grinding wheel drift, which insures truth in the hole (limited only by the precision of the work holding spindle and traverse).
4. Surface finishes of 2 microinches rms or better without extraordinary preparation.
5. Reduced bell mouth and "fall in" on interrupted or ported bores.
6. Improved finish and truth for a given floor to floor time when production rate is paramount.
7. Convenient and rapid change of governed operating speed over a wide range.
8. Ability to run the spindle axis at any angle to the horizontal since the air bearings are unaffected by tilt.
9. Essentially constant speed control with a governor droop less than needed for the most precise work.
10. No generation of local heat that could influence the associated machine accuracy.

Two development models are shown in Fig. 1. Unit (A) can be adjusted to hold any selected speed within the range 30,000 to 50,000 rpm and may be used with wheel diameters from $\frac{3}{4}$ to $\frac{1}{4}$ in. Unit (B) has a speed range of 60,000 to 100,000 rpm and normally carries wheels or points $\frac{3}{8}$ to $\frac{5}{32}$ in. dia. The body castings are machined to suit a popular make of hole grinder, and adapters can be made to

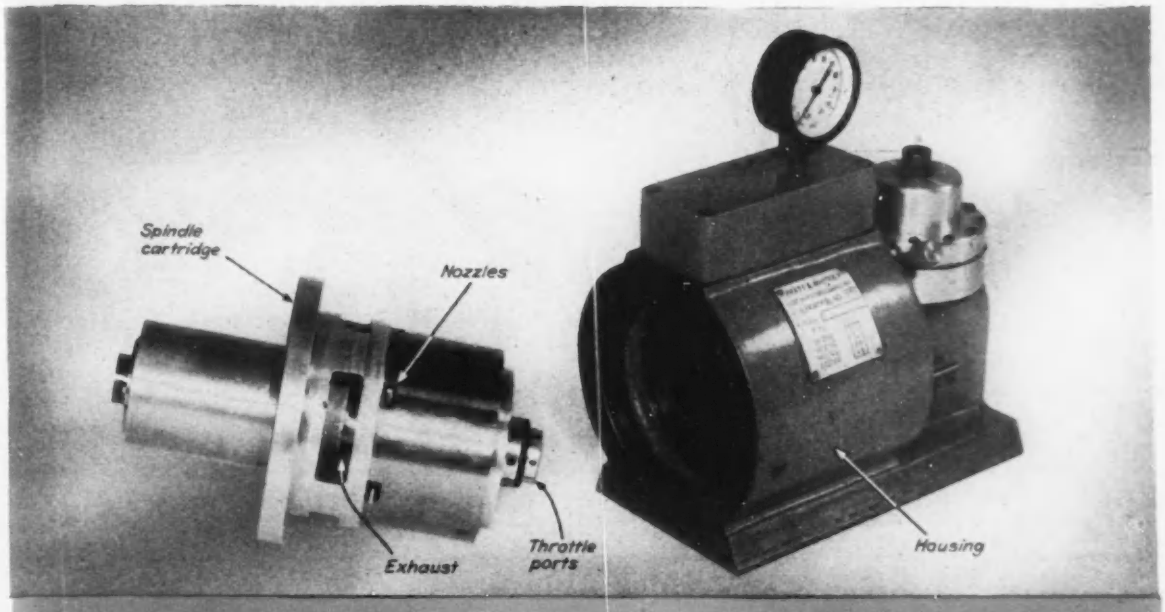

Fig. 2—Spindle cartridge unit and its housing. The cartridge contains the bearings, spindle, turbine runner, governor and throttle valve. From four to eight nozzles are used depending upon service load required by the particular application.

for Internal Grinding Machines

suit any of the usual grinding head mounts.

Shop air is connected by a flexible $\frac{3}{8}$ in. hose at the rear of the housing. An internal passage connects the air line directly to the reducing valve, which delivers a steady pressure nearly independent of line fluctuations to the speed governor. This passage also connects to the air lubricated bearings, which are kept under pressure whether the spindle is in operation or shut down. A start-stop lever opens or closes a simple plug valve between the supply and the turbine. The speed selection needle valve is used, in conjunction with the speed chart and the nozzle pressure gage, to choose the speed at which the governor is to control. An expansion chamber or muffler reduces the noise of the exhaust to a low level.

In Fig. 2 is shown the spindle cartridge, removed as a unit from the housing. The cartridge contains the bearings, spindle, turbine runner, governor and throttle valve. From four to eight nozzles are used depending upon the service load required by the particular application. The nozzles have a carefully made venturi flare with an expansion ratio to use the air efficiently. The controlled air to the nozzles is contained in an annular chamber just visible in the housing and sealed from the line supply and the exhaust by rubber O-rings; one large ring in the housing and a smaller ring at the throttle ports. The gage is connected to this annulus and indicates nozzle pressure.

Further detail is revealed in the dismantled cartridge shown in Fig. 3. The front bearings are in the flanged nose housing (A). The spindle and Terry type runner are shown at (B). The rear bearings are in the governor and nozzle housing (C). These views are of the 50,000 rpm unit. To give an idea of the size of the parts, the front journal is $1\frac{3}{16}$ in. dia and the runner rim about 3 in. dia. The OD of the thrust bearings is approximately 2 inches.

In this model the bearing material is ordinary bronze and the spindle is hardened steel. The criterion for choice of bearing materials is quite elastic because the rubbing parts are always separated by an air film. It is only required that the materials be impervious (not porous) to air and not corrodable by the usual moisture, oil and varigated whatnot delivered through the shop air lines.

The runner is of extruded aluminum alloy bar stock, with machined buckets. This type of runner was chosen for its simplicity and ruggedness rather than from considerations of efficiency. This form is not as good in small diameters as a radial in-flow design for example, but when the operating cost for air supply (10 to 20 cents per hour) is taken into consideration the efficiency factor can take second place.

Aluminum running against bronze as a thrust bearing doesn't make sense, particularly at 50,000 rpm on a 2 in. dia, until it is remembered that there is no contact and that the lubricant is air with a viscosity far below that of oil. The restriction jets described in "Air Lubricated Bearings," PRODUCT ENGINEERING, August 1951, p 112, which supply the differential air pressure on which bearing action depends, are easily visible on the thrust faces. Their equivalents in the journal bear-

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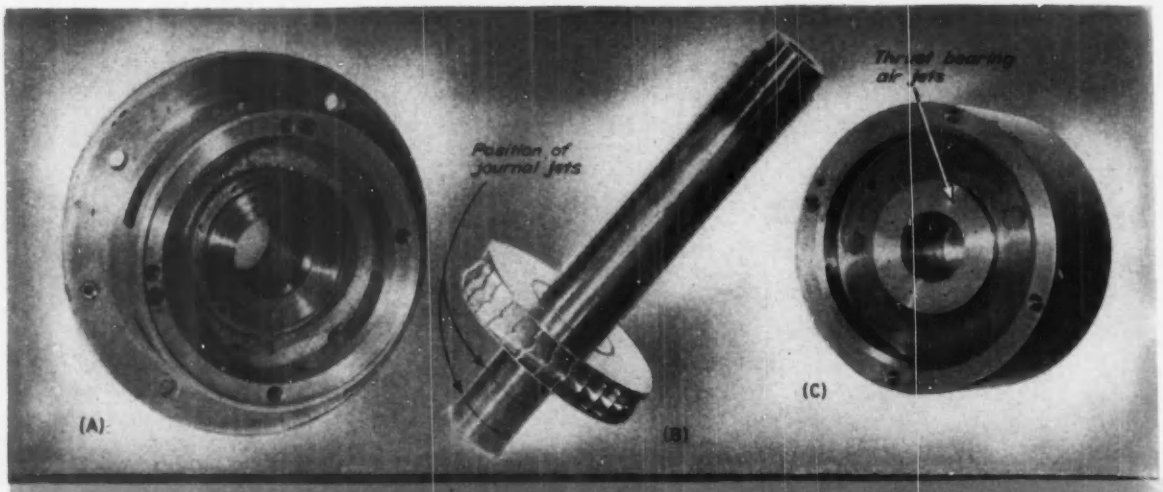

Fig. 3—Dismantled cartridge. (A) Flanged nose housing, the front bearings are in this housing. (B) Spindle and runner, runner is extruded bar stock in which buckets are machined. (C) Governor and nozzle housing, the rear bearings are in this housing.

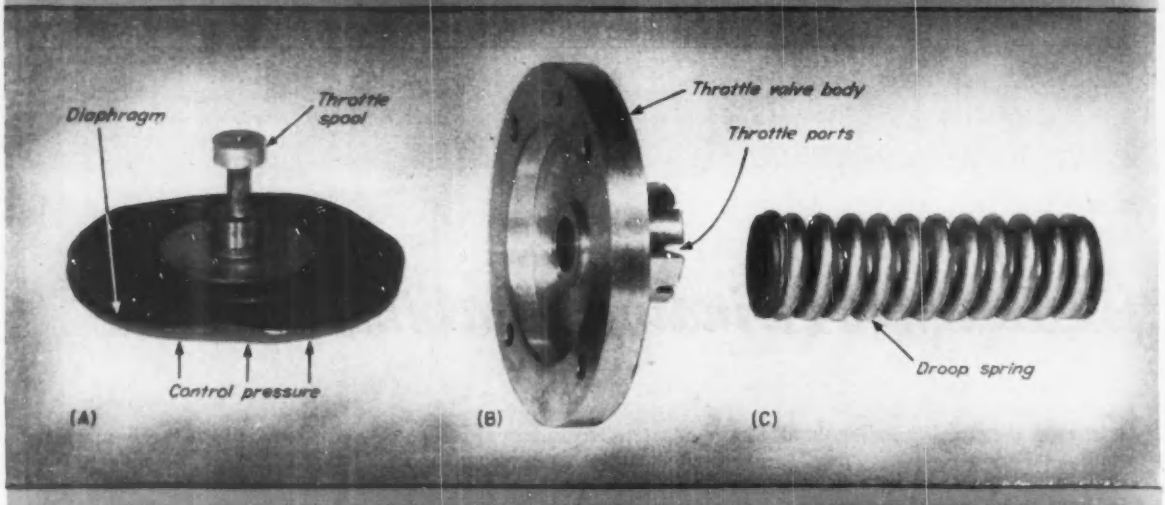

Fig. 5—When unit is assembled, the throttle spool extends through the throttle valve body and is urged to the left by the droop spring. When the governor is cut in, the droop spring force just balances the control pressure force acting on the plastic diaphragm.

ings are not evident from Fig. 3 but their positions can be judged from the two dark rings on the rear journal. These rings are carbonaceous deposits from the air line supply, which were not wiped off at the time the photograph was taken.

The governor proper can be seen to good advantage in Fig. 4. The centrifugal fly weights are a ring of cantilevers formed by slotting a thin metal tube. Under centrifugal force these cantilevers bend out radially.

The inner diameter of the outer ends of the cantilevers is carefully ground, concentric with the spindle, to a diameter that will just slip over the plug, which can be seen at the bottom of the rear journal. This plug is cross-drilled to form a small orifice, which is very nearly sealed by the governor cantilevers when the spindle is at rest. This orifice is a bleed from the control air system.

As the turbine is brought up to speed the cantilevers spring away from the seal and increase the bleed. The rate of bleed thus can become a measure of the amount of deflection and in turn a measure of the speed of the spindle. It is this characteristic that is used to regulate a selected speed and to select the desired speed.

The simplicity of the cantilever governor accounts for its ability to regulate with very small droop. There are no links, levers or pivots to introduce backlash and friction, hence, governor hysteresis is limited only to the internal friction in the metal of the cantilevers, which is vanishingly small. For the 50,000 rpm turbine the inner diameter of the cantilever ring is $\frac{5}{16}$ in. Its initial seal is less than 0.0001 in., which is opened to 0.0012 in. at half speed and to 0.0045 in. at full speed.

The plug and orifice connect directly to the pressure side of the plastic diaphragm shown in Fig. 5(A). This diaphragm is fastened to the rear housing by the flanged throttle valve body (B). The throttle spool extends through the valve body and is urged strongly to the left by the heavy spring (C), which when the governor is cut in, just balances the control pressure force on the diaphragm. Any reduction of control pressure closes the throttle and an increase opens it.

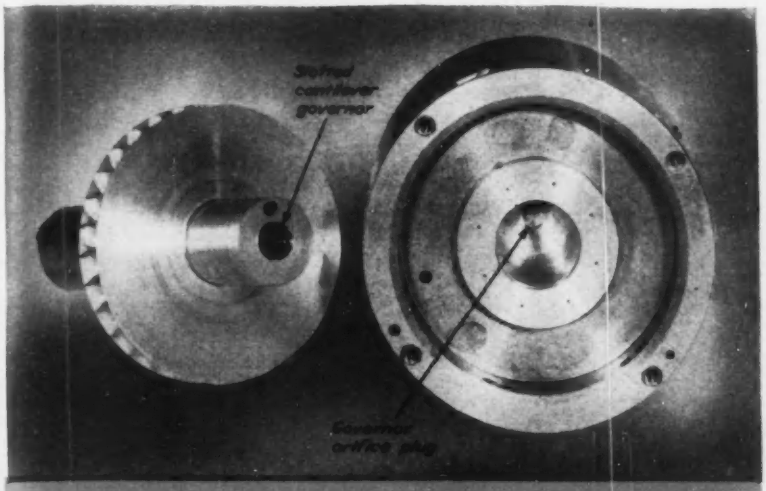

Fig. 4—Cantilever governor is at inner end of spindle. Governor orifice is a small hole cross-drilled in plug. Governor assembles over the plug.

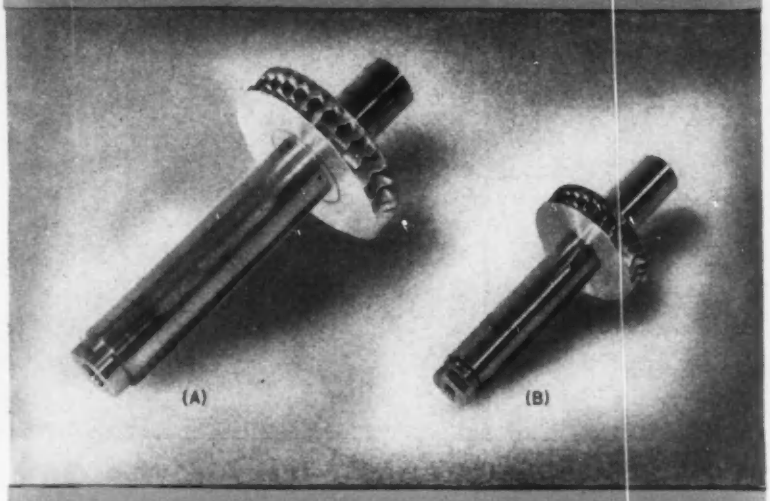

Fig. 6—Relative sizes of runners for a complete range of speeds. (A) Runner for 30,000 to 50,000 rpm range. (B) Runner for 60,000 to 100,000 rpm range.

Bleed at the cantilever seal determines the control pressure and thereby determines the degree of throttle opening. The parameters of the design are such that the throttle cracks at 40 psig and is completely open at 45 psig. This pressure acting on the effective area of the diaphragm, about 2½ sq in., balances the heavy actuating spring. The rate of the spring determines the sensitivity, all other things being constant; a high rate increases the droop and a low rate decreases the droop.

By adjusting the amount of bleed air passing through the control system, the desired speed is pre-set. Air under a constant pressure from the reducing valve, Fig. 1, is metered at the speed selection valve as the air goes into the pressure side of the diaphragm, which when governing is always near 42 psig. This same amount of air must need escape from the orifice at the governor cantilever.

The speed of the spindle must therefore be such that the balance is met, otherwise the diaphragm pressure will change and the throttle will open or close to bring the speed to a point where control air bleed equals the inlet rate. Thus, if the speed valve is adjusted to pass only a small amount of control air, the cantilevers need spring away from the bleed orifice only a small distance to equal this flow. This adjustment is equivalent to low speed setting. Contrarily, if the speed valve is opened to pass a greater amount of flow the cantilevers must open wider to balance the rate. This adjustment is equivalent to high speed setting.

This convenient and rapid method of changing speed is of particular advantage when installing new grinding wheels. When first mounted these wheels are generally eccentric and potentially dangerous if run at high speed for the dress. By reducing the speed to a safe value, the wheel can be hand stoned into balance after which the speed may be brought up for the finish diamond dress.

In Fig. 6 is shown the relative sizes of two runners for a complete range of speeds. Runner (A) has a range of 30,000 to 50,000 rpm; and runner (B) has a range of 60,000 to 100,000 rpm.

The 50,000 and 100,000 rpm spindles have been redesigned for quantity production. The redesign follows the principles described for the development models but differs in one important respect. This difference permits a more economical adaptation to a wider variation in the air supply conditions.

To function most satisfactorily, the bearings and the control require a source of air having a minimum of 90 psig and a variation of pressure of not more than 10 percent, a condition not always encountered in the shop. The power air, that is, the portion of the supply that drives the turbine, need not be well regulated because the governor takes care of any fluctuations. The bearing and control supply quantity is minor, the bulk of the air being needed for driving power.

The redesign takes these points into consideration and permits the turbine to be run either from (1) a single well regulated source, or (2) from two sources only one of which need be well regulated for the control. The first arrangement is most economical for an installation where only one or two spindles are needed. Where a larger number of spindles might be used on a bank of production grinders, the second arrangement is likely to be best. A small separate compressor installed near the bank can be justified for a multiple grouping and will insure a proper supply for the bearings and control.

A number of development spindles have been built and used on a variety of jobs ranging from pump cylinder liners, where the finish is 1 to 2 rms micro inch and the truth tolerance is ± 0.000005 in., to automatic cycle grinding of ball bearing bores, where finish and tolerance are not extraordinary but cycle time is in the order of 15 to 20 seconds. The results have been quite successful and it is anticipated that further shop experience will be equally favorable.

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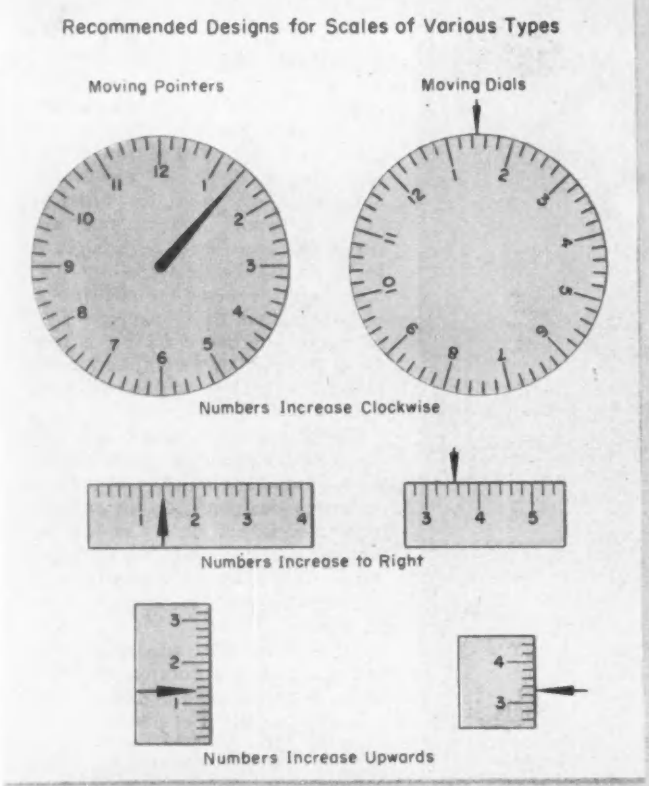
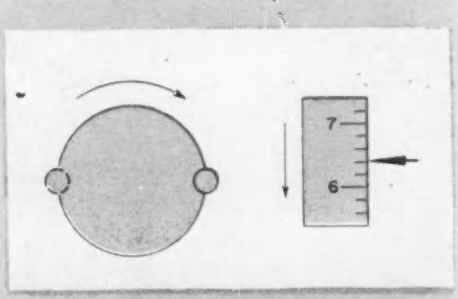
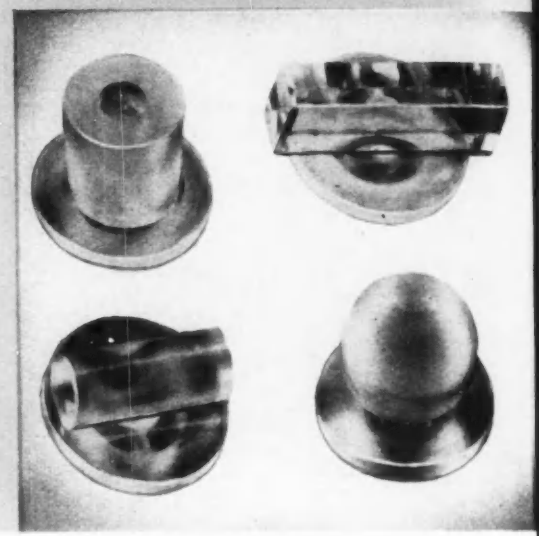


The coding of controls by shape can reduce the number of errors caused by confusion. At Wright Field tests were made on knobs for ideal relation to purpose and for discrimination. The knobs shown above are from a group found to yield zero error.



Satisfactory control-indicator relationships for open-window dials. Clockwise control movement produces increased indicator reading, and a counter-clockwise movement a decrease.



Fitting Machines to Men

THE APPROACH TO THE PROBLEM of fitting the machine to the operator is called human engineering, which means essentially designing machines that can be operated by people with normal human abilities and limitations. This approach is characterized mainly by systematic thinking, supported by data obtained through research in applied experimental psychology.

The first step is to analyze the operation and define its objectives, whether the job concerns counting pills, inspecting crankshafts, or piloting a plane. The second step is to find out how well these objectives are being, or can be attained. The third is to find out what factors limit the attainment of these objectives, for example, to what extent does the equipment restrict the performance of the operator. The last step is to determine what can be done about these problems.

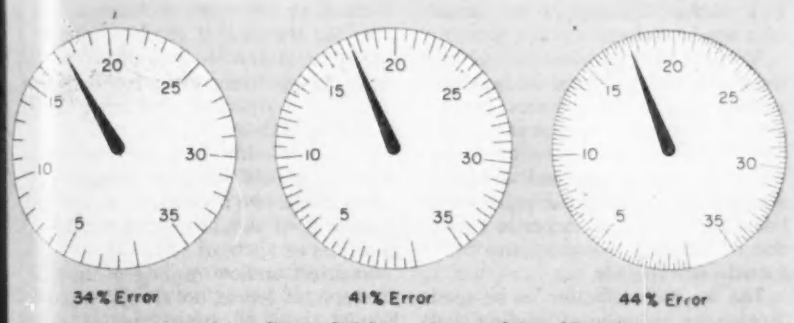
General methods are used commonly to obtain such data.

ACTIVITY ANALYSIS. A detailed study of how an operator functions with existing equipment often indicates changes that will result in less fatigue, more production, fewer rejects, better morale, improved safety and reduced cost.

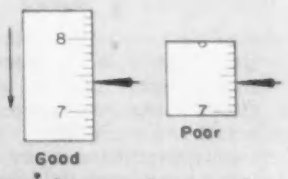
This can be done by time-studying an operation and making detailed notes on what the operator does. Frequently, motion picture cameras can be used to obtain a permanent record which can be studied and analyzed at leisure. This technique provides answers to questions such as:

1. Are the controls properly designed, positioned and of the correct sensitivity?
2. Are the switches and indicators of the right type and properly grouped?
3. Are emergency controls provided where needed?

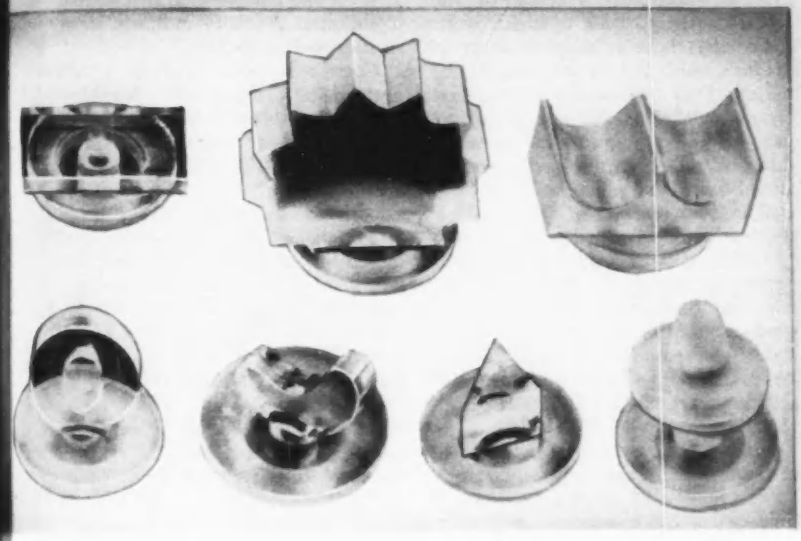
If information is the critical item flowing through a system, recordings can be made of conversations between personnel at various work stations.

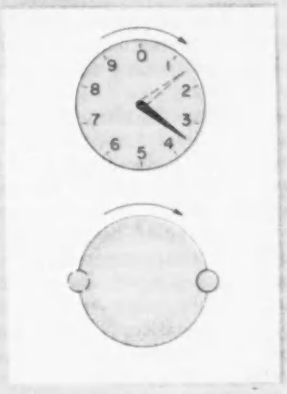


Accuracy in reading a dial is not improved by adding fine subdivisions. Figures under each dial indicate the percentage of error in reading the dial with exposure of $\frac{1}{4}$ second.



To reduce error for open window dials, the windows should be made large enough to permit two complete numbers to be shown at all times.





With a moving pointer, a clockwise movement will indicate an increased reading. Control and pointer should move in the same direction.

- Establishing engineering specifications for machines or equipment often is only half the job.
- Considering the operator as a basic part of the design problem may materially improve machine efficiency to a great extent.
- Here are techniques of Dunlap and Associates, Inc., a firm that applies them in their work for both industry and government.

Analysis of these recordings often reveals trouble spots, such as over-loaded circuits, and frequently visual signals can be suggested which will relieve the load. By incorporating these sound recordings with an activity analysis, it is possible to predict the operator's actions when responding to instructions, and to determine the efficiency and effectiveness of both the equipment and system that is used.

Naturally, the opinion of the operator is always valuable in obtaining design data. However, opinion is less reliable than fact. Reliability can be increased by sampling the opinions of a large group through the use of questionnaires. But these results should be checked by direct observation wherever possible.

MODEL ANALYSIS. Constructing a model of new equipment and studying it in the laboratory often brings out changes that should have been obvious but somehow were missed The model may also be given to operators who have used similar equipment before, to obtain their reactions and suggestions.

Depending on the type of equipment being designed, model analysis may or may not be more effective than activity analysis. It seldom is used as the initial step unless there is no existing equipment of a similar nature, but it frequently is a valuable tool if supplementing an activity analysis is desired.

CONTROLLED EXPERIMENTATION. Setting up a controlled experiment in the laboratory permits analysis of the effect of design on operator performance. This is a research approach and may be applied to a comparison of ele-

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ments of a given machine, such as indicator dials, or a comparison of various operating procedures.

What Should Be Studied

In general, factors to which particular attention is given in any research and design program can be arbitrarily grouped into two categories: environmental and machine.

In the environmental category are such factors at temperature and humidity, lighting, and noise. If ventilation is poor in the area in which the machine will be placed, heat producing units should be separated so that the heat is distributed over as large an area as possible. Vents should be so placed as to direct heat away from the operator. Adequate space should be left between all machines, not only for purposes of cooling but to permit easy maintenance.

Color of the machine should be selected not only for appearance, but to provide good color contrast under the type of lighting that will be used. Dial lighting and supplementary machine lighting should be provided if necessary. If certain meters or indicators must be separated from others and even grouping does not give sufficient discrimination, the groups should be outlined in color or colored meters should be used.

In the category of machine factors are such items as (1) dial indications; (2) machine controls; (3) machine dimensions; (4) selector switches; (5) machine mounting; and factors of a similar nature.

Visual indicators are one of the more important points of study. There are two types of scales commonly used as visual indicators: circular and linear. Each has two sub-types—a fixed dial with a moving pointer and a moving dial with a fixed reference point—and linear indicators can further be classified by whether the scales run horizontally or vertically.

The type of indicator to be used depends on the type of reading that is required. One indicator might be preferred for a check reading, another to note qualitative changes in operating conditions, and still another to give a quantitative reading or the actual numerical value of a change.

For the check reading of a group of indicators, the display should be patterned so that, under normal operating conditions, the pointers of all gages will be pointing in the same direction. Best results have been obtained when normal conditions are indicated by pointers in the 9 o'clock position. Other accepted principles are:

1. Accuracy of reading is not improved by use of a dial with extremely fine sub-divisions, particularly on production equipment.

2. Numbering small sub-divisions decreases, rather than increases, the accuracy with which a dial can be read at a glance.

3. A moving pointer is better than a counter if the change of indication is rapid, or when one is interested in knowing the rate of change.

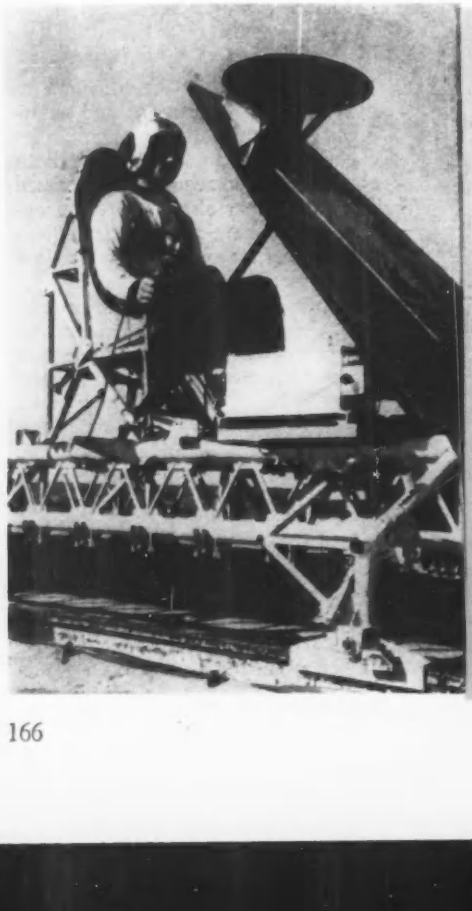
A control and its indicator should move in the same direction, with a clockwise movement indicating an increased reading.

If open window dials are used, the windows should be large enough to show at least two numbers at all times.

Scale units should be numbered in multiples of 5, 10, or 100.

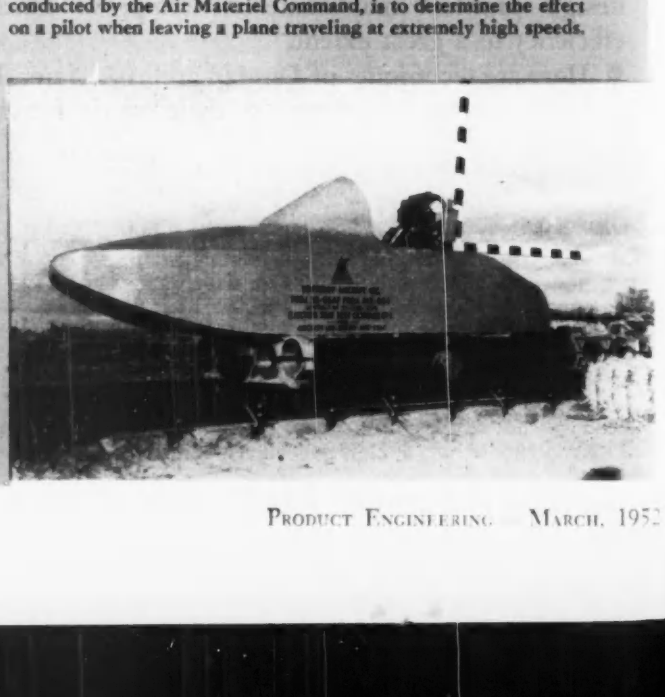
Incorrect or slow reading of an indicator is, of course, not always serious. Results could be trivial, as for example, the misreading of an altimeter while flying at 20,000 ft over level terrain. But the same error could be serious when flying over mountains. It is for the latter reason that so much attention is given to indicator design in human engineering.

Correct design of controls is, however, equally important. Magnitude and type of load, sensitivity of the control type of motion, amount of load feed-back, and control location are some of the significant factors. Usually the magnitude of the load is one of the first considerations because the ability of the operator to control it, whether by pushing, pulling or turning, determines whether the load can be directly geared to the control lever or whether power operation is desirable. In all cases of power operated controls, some "feel" should be left to the operator, either by deliberately designing into it a synthetic resistance to movement, or by having



READY for another deceleration ride. Disk at upper edge of windshield supports a small, sensitive telemetering antenna, which broadcasts signals of volunteer's reactions during test. Chassis has been stressed for 100 "g's", with 50 percent safety factor.

THIS SLED-LIKE CARRIAGE races down a two mile track at speeds up to 1,100 miles an hr, and at its maximum speed catapults a dummy from an ejection seat. The purpose of the test conducted by the Air Materiel Command, is to determine the effect on a pilot when leaving a plane traveling at extremely high speeds.



power operation take over only after the operator exerts a certain amount of pressure. This resistance to movement can be linear, so that the same force must be exerted regardless of the position of the control, or it can be differential, so that increased force is necessary as the control is moved further away from dead center.

Sensitivity of the control is closely tied in with the type of control motion. A wheel gives excellent sensitivity and flexibility, but the correct gearing is necessary to eliminate unnecessary turning and provide correct leverage. A lever gives almost the same amount of precision, but is limited in movement to the length of the operator's arm. From this standpoint, the location of the control, especially in a confined work space, frequently governs the choice of motion.

Increased sensitivity can be provided by using different gear ratios, one for fast moving control and another for vernier or fine adjustments. A combination wheel and lever is one way of accomplishing this. Another is a two-position wheel or knob that in normal position permits fast moving adjustments but in a detent position gives a fine control.

As with indicators, the direction of movement of the control should follow the movement of the equipment, and if possible the shape of the control should be indicative of its function. Visual discrimination is particularly important when there is a multiplicity of control elements, as in an aircraft cockpit. As a matter of fact, the Air Force has been experimenting for some time with basic knob shapes that permit maximum discrimination by feel. Work on this project is continuing, the goal being the largest possible number of shapes without sacrifice of accuracy.

Of course this problem of controls depends somewhat on whether a new design or a redesign is involved. Retraining an operator may or may not be justified by the advantages that are gained through redesign. A decision to redesign, therefore, must take into consideration the amount of retraining required, and must be based on the abilities of the average operator. Usually no such limitations are imposed on designs for entirely new equipment. The problem here comes down to getting the best control, in the best position, and if possible, in the correct pattern for operation.

In respect to position, machine height and chair height have a significant effect on operator fatigue or efficiency. The position of a clutch on a tractor, a scope on a radar viewer, or a control stick in an airplane in relation to the normal operator position, and placement of indicators are examples of some of the factors that must be considered. Although the old approach was to so position the operator that he had to move around to run a machine, constant changing of position can easily cause mistakes in reading of indicators and making control corrections.

Although emphasis has been placed on industrial and military equipment, analyses of the above types apply equally well to consumer products. A typical case is that of an electric stove, the details of which are as important to the housewife as the design of a machine tool is to the operator. Design factors influencing customer satisfaction can be determined by the techniques previously mentioned. Use of these techniques in product development can have a favorable effect on customer reactions and sales.

Integration of Equipment Into Systems

All of the foregoing considerations frequently are influenced by the system into which a machine must be integrated. Consider, for example the problem of manufacturing and distributing electrical power to meet the demands of a community. The power plant for any community is a common example of a complex system of men and machines. The performance of this system is directly affected by the demands made upon it as well as by the various factors contributing to the generating of power. The basic objective of the system is to maintain an optimum balance between supply and demand. To do this various subsystems of men and machines must be employed, such as fueling, generating, switching, lubricating, maintenance and communications. First a backlog of information must be built up and overall decisions made on the general characteristics of the system:

1. What are the anticipated demands for given periods in a 24-hour cycle?
2. What is the optimum supply that must be generated to meet these demands?
3. How important are minor deviations from the anticipated demand?
4. What action must be taken to adjust to these deviations?
5. How are the various sub-systems affected by changes in demand?
6. To what extent is the supply affected by breakdowns in the subsystems?
7. To what extent can neighboring plants be drawn upon in emergencies?
8. How are emergencies in neighboring systems likely to affect performance in this system?
9. What are the communication requirements between systems?
10. What information do the various plant operators need to perform their tasks?
11. How may this information best be presented to them?
12. What are the speed and accuracy requirements of the various tasks?
13. How should the controls and indicators be designed and arranged so that the performance requirements can be satisfied?
14. To what extent do work environment factors, such as light, heat, noise and vibration affect performance?

With all these facts known, the next step is to design the equipment to do the work. A particular system must be set up and tested, and decisions regarding individual elements in the system made from these tests. After the technical features of these elements are decided upon, the problem is narrowed down to cost, availability, and practicability; or, the choice of cost against performance. The details are given to the designer with the recommendations to use accepted modes of design, such as color, size of lettering, and shape. Then a model is made and analyzed.

This analysis covers the finer points of the design from the human engineering standpoint. Take, for instance, a switchboard unit. These points must be considered.

1. Size of the panel
2. Color of the meters and background
3. Glare protection
4. Location and arrangement of controls and displays according to importance
5. Design of specific controls and indicators
6. Communication facilities
7. Emergency signals
8. Record-keeping facilities
9. Operating instructions and regulations
10. Training programs.
11. Factors inducing boredom

The jet fighter plane is perhaps the best indication of how increased speeds and modern design are making the once simple job of flying into a complex procedure. New propulsion units have increased the speed, added more dials and controls, and reduced the time with which a pilot may observe the dials and make decisions from them. Good design of the cockpit and the control panel probably will not reduce the number of elements, but it will make operation easier and less subject to error.

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PART II

TORSIONAL FATIGUE FAILURES

J. O. ALMEN
Research Laboratories Division, General Motors Corporation

Analytical studies of fatigue fractures in torsion bar springs for military vehicles that, in spite of inherent planes of weakness, show that torsional fatigue failures are caused by and develop normal to the tensile component of the applied stress. Data bearing on the characteristics of torsional failures obtained from fatigue tests of torsion bars that were subjected to experimental variations in processing.

SUBSTANTIAL EVIDENCE was presented in the article "Torsional Fatigue Failures," PRODUCT ENGINEERING, September 1951, p 167, to show that tensile stress is the direct cause of fatigue failures from repeatedly applied torsional loads. Data presented in that article also show that the compressive stresses contribute to fatigue failure only in an indirect manner through altering the yield strength of the metal.

In the discussion on Torsion Bar Springs in the latter part of that article, data obtained by the dissection process were presented to evaluate the residual stresses in a specimen cut from a torsion bar spring, which was made of NE 9262 steel, heat-treated to a uniform hardness of Rockwell C49-50. In the final processing, these bars were prestressed by shot peening and by overloading in the direction of the normal service load.

It was seen that the fatigue strength was much greater in torsion bars that were shot peened before pre-setting than when the opposite sequence was followed or than when shot peening was omitted. In terms of nominal

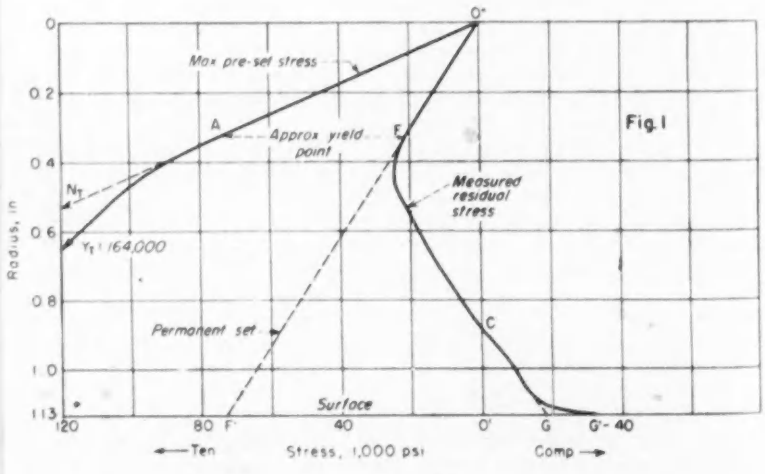

Fig. 1—Residual stress in a tank torsion bar spring. Reconstructed from dissection measurements showing reduced surface tensile stress, magnitude of permanent set, and yield stress of surface and sub-surface metal.

Fig. 2—Tank torsion bar spring diagrams. (A) Favorable residual stresses induced. (B) Loss during processing. (C) Resulting operating stress ranges.

stress, the twisting or pre-setting was approximately 255,000 psi, which stress exceeded the yield strength of the bars.

When shot peening preceded the pre-setting operation, the vulnerable surface became biaxially stressed in compression by an amount approximating one half of the yield strength of the steel.

The data as revealed by the dissection measurements on the torsion bar spring specimen are shown in Fig. 1. These data, together with an interpretation of them to a lower order of accuracy, are reported in Fig. 2. The diagrams of Fig. 2 also differ from Fig. 1 in that they present the data in terms of tensile and compressive stress components in the manner shown in Fig. 3. The construction of diagrams such as Fig. 3 were discussed in the September 1951 article. These diagrams show separately the magnitudes and distribution of biaxial tensile and compressive stress components extending from the surfaces of torsion specimens to their neutral axes.

The diagonal line N_tN_c Fig. 2(A) represents the nominal tensile stress compressive stress component N_tO'' and the compressive stress component $O''N_c$ that resulted from the torsional prestress of 255,000 psi. Each component is arbitrarily given the same value as the resultant torsional stress in Fig. 1. The point A on the diagonal N_tN_c indicates the initial subsurface yield stress in the direction of the tensile stress component, and the point B indicates the initial sub-surface yield stress in the direction of the compressive stress component. Since diagram Fig. 2(A) expresses biaxial stresses, the points A and B are actually coincident (the stresses at these points correspond to the torsional yield stress at A in Fig. 1), and are presumably equal in magnitude.

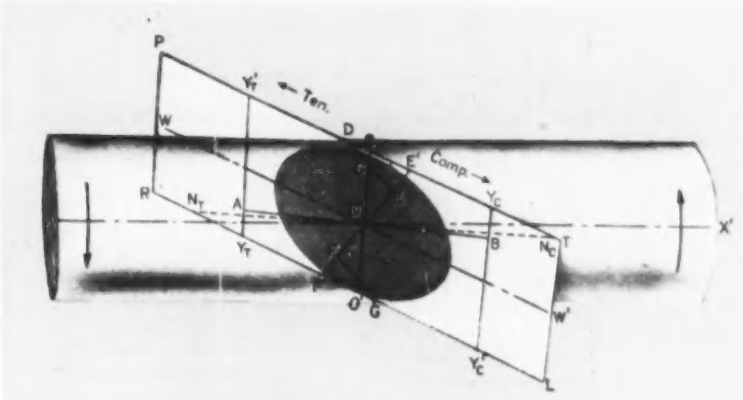

Fig. 3—Diagram showing tensile and compressive stress components of torsional moments.

Since the nominal torsional prestress N_tN_c exceeded the yield strength of the steel, the maximum surface stress was considerably less than 255,000 psi. Based on the residual stress data shown in Fig. 1, but not including the stress remnant GG' from shot peening, the surface tensile and compressive yield stresses were less than the nominal applied stress by an amount equal to the total plastic yielding $F'G$. By measurement, $F'O'$ equals 73,000 psi and $O'G$ equals 18,000 psi. From these data the extent of yielding in the direction of both components is taken as 91,000 psi. The surface yield strengths $O'Y_t$ and OY_c, Fig. 2(A), are therefore

$$255{,}000 - 91{,}000 = 164{,}000 \text{ psi}$$

The yield stresses at intermediate depths range from 164,000 psi at the surface to 71,000 psi at the depth A, somewhat as represented by the straight lines Y_tA and Y_cB.

The indicated yield strength of the cold worked surface metal, as well as the initial yield strength of sub-surface metal, is seen to be at variance with the values that would be expected from conventional yield stress determinations. This instance is the only one known to the author in which the pattern of torsional yield stress has been determined from residual stress measurements. The method appears to be inherently more accurate than the conventional method in which an assumed yield pattern is constructed upon static yield measurements. Additional dissection measurements of residual torsional stresses will be required to establish the relative merits of the two methods. This comparison should also be made for specimens that have been loaded above their yield strengths in bending, tension, and compression.

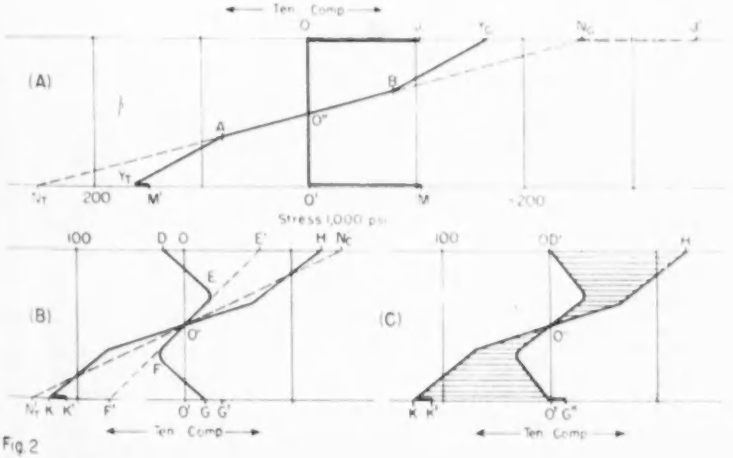

Fig. 2

Shot Peening Residual Stresses

Approximations of the biaxial residual stresses that were induced by the shot peening operation are also shown in Fig. 2(A). This diagram also shows the dissipation of most of these stresses when the torsion bar was subsequently pre-set by overloading.

As previously explained (Refs. 1 and 3), adequate shot peening induces biaxial residual compressive stress ap-

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proximating one half of the nominal yield stress of the peened metal. The nominal yield stress of steel having a hardness of Rockwell C-49-50 may be assumed to exceed 200,000 psi, from which the biaxial (compression-compression) peening stress induced in the torsion bar is assumed to be slightly greater than 100,000 psi as indicated in Fig. 2(A) by the stress components OJ and $O'M$.

The nominal compressive and tensile stress components at the surface of the torsion bar from the prestressing overloads were 225,000 psi; but since these stresses were superimposed upon the residual biaxial compressive stress induced by shot peening, the total nominal stresses for the immediate purpose are assumed to be the algebraic sums of the residual and applied stresses. The combined nominal stress in the direction of the compressive component of the torsional stress is therefore

$$OJ + ON_c = OJ'$$

Since this sum exceeds the yield stress of the metal by the amount Y_cJ', it is seen from this observation that all of the peening stress in the direction of the compressive component is immediately lost.

The combined nominal stress in the direction of the tensile component is

$$O'N_t - O'M = O'M'$$

In this direction, the portion Y_tM' of the peening stress remains, but the greater portion N_tY_t was dissipated by plastic yielding.

Tensile Yielding Reduced

One effect of shot pending on the vulnerable surface layer was to reduce plastic yielding in the direction of the tensile component by the amount N_tM' and to increase plastic yielding in the direction of the compressive component by the amount N_cJ'. It is not known whether the damage caused by extensive plastic yielding was reduced by this exchange or if the increased fatigue durability (shown in Fig. 17, p 179, Ref. 4) resulted solely from decreasing the magnitude of the applied stress in the direction of the tensile component.

After release of the prestressing load, the two residual stress components in the bar were as indicated by the broken line $DEFGG'$ in Fig. 2(B). It is seen that the residual stress $O''FGG'$, in the direction of the nominal tensile component of this diagram, is identical with $O''FGG'$ of the torsional diagram Fig. 1 including the remnant GG' of the peening stress. The residual stress DEO'' in the direction of the nominal compressive component of Fig. 2(B) is also like the diagram Fig. 1, except that it is inverted and no portion of the peening stress remains.

Tensile Component Reduced

The maximum load that was applied during the fatigue test stressed the torsion bar to a nominal value of 145,000 psi, as is indicated by the diagonal dash line $N'_tN'_c$, Fig. 2(B). The maximum stresses were the algebraic sum of these nominal applied stresses and the residual stresses, as indicated by the broken line $K'KH$. It is seen that the combined effect of prestressing by overload and by shot peening reduced the tensile component of the applied stress by the amount N'_tK'. The surface tensile component, which because of surface weakness (Ref. 2) is the direct cause of fatigue failures in specimens that are not adequately prestressed, was thus reduced from 145,000 to approximately 113,000 psi.

The diagram Fig. 2(C) indicates the stress range that was applied during the fatigue test as modified by the residual stresses from the nominal unidirectional range of 20,000 to 145,000 psi. It is seen that, in approximate terms, the surface compressive component $D'H$ ranges from 2,000 psi compression to 127,000 psi compression, and that the surface tensile component $K'G''$ ranges from 113,000 psi tension to 12,000 psi compression.

This method, as used in the preceding paragraphs for combining the biaxial residual compressive stress from shot peening and the biaxial torsional stress from the prestressing overload, is an oversimplification that leads to errors in the resultant stress magnitudes. Although these quantitative errors are undesirable, it is believed that the diagrams of Fig. 2 correctly represent the qualitative effects.

Combining Biaxial Stresses

A more accurate method for combining such biaxial stresses has been developed by Mr. Robert Schilling of the Research Laboratories Division, General Motors Corporation. This method, which makes use of the conventional yield ellipse, is being prepared for early public presentation.

The Schilling method will indicate that less plastic yielding occurred from combining the peening and pre-setting stresses than is shown in Fig. 2(A). It will also indicate that a small peening residual stress was retained in the direction of the compressive component (upper part of diagram) as well as a greater stress in the direction of the tensile component (lower part of diagram). The retaining peening stress components were, of course, unequal in magnitude else no peening stress would have been detected by the dissection stress analyses.

The net effect of the Schilling method is expected to be that the (harmful) surface tensile stress is reduced by a greater quantity than KK' as is indicated in Fig. 2(C) with corresponding increases in the compressive stresses of the same diagram. Since this latter increase is in the elastic range, it does not affect the fatigue strength of the specimen.

Prestressing at High Temperature

It is probable that the greater part of fatigue damage from extensive plastic yielding could have been avoided by performing the prestressing operation at an elevated or higher temperature.

The production tempering specification required a ". . . minimum time at heat of two hours at not less than 850 F to produce hardness of . . . 47-51 Rockwell C." Presumably, therefore, prestressing could have been performed at a temperature where the bars were more ductile and plastic flow could occur with relatively less fatigue.

This precaution was observed in straightening the bars after heat-treatment. According to specifications, the straightening operation was "performed " . . . from draw heat at a temperature of not less than 600 F." Even at this temperature, straightening by applying a bending load could be extremely damaging to those hard torsion bars, because the process induced residual tensile stress on one side of the bar and required yielding by direct tension on the opposite side. Direct tensile yielding could, and probably did, develop transverse cracks in bars that required extensive straightening.

A number of experimental bars were given a second shot peening after pre-setting, which presumably increased surface residual compressive stress but it also required additional plastic flow. Tests of these doubly shot peened bars did not show greater fatigue life than resulted from a single peening prior to pre-setting. In one case the double treatment indicated a loss in fatigue strength, which is a relatively common experience with overpeened parts, but it is more probable that the loss in fatigue strength was due to defective material than to overpeening.

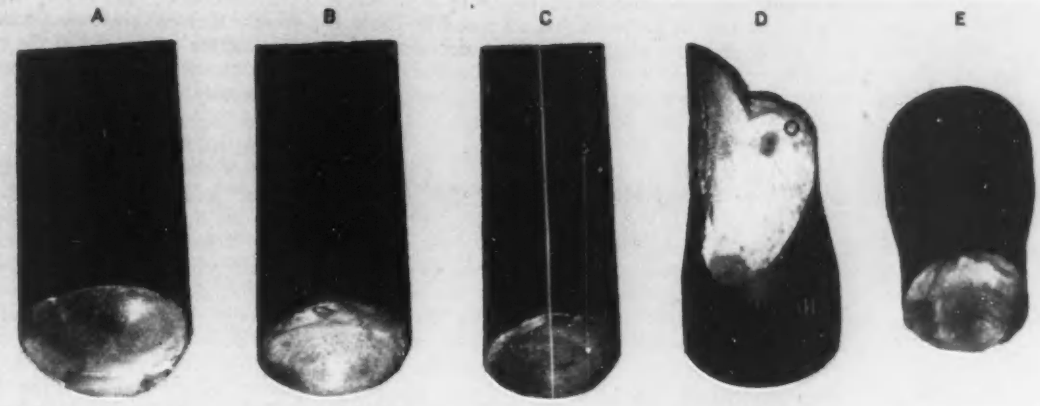

Fig. 4—Decarburization and consequent extensive plastic yielding during unidirectional fatigue tests caused shear failures in four of five bars.

Table I—Yield and Fracture of Torsion Bar Specimens

Torsion Bar	Decarb. Depth, in.	Core Hardness, RC	Cycles Failure	Yield, in.			Longitudinal Defects	Character of Fracture
				5,000 Cycles	10,000 Cycles	20,000 Cycles		
A			43,000	0.835			Short	Shear
B			29,000	0.793			Short	Shear
C			30,000	0.665		0.96	Short	Shear
D	0.009	47	40,000	0.710	0.72		Short and long	Tension
E	0.018	47	25,000	0.751		0.84	Short	Shear

Processing Variations Reveal Valuable Data

As a result of numerous experimental variations in processing of military vehicle torsion bars and because the effect of each variation was measured by many fatigue tests, valuable data bearing on the characteristics of torsional failures are available. Among these are transverse and longitudinal fractures that tend to confuse the observer as to causes of fatigue and the remedial measures that may be applied.

The characteristics of fractures that developed in five experimental torsion bars from applying repeated unidirectional twisting loads ranging from 38,000 to 137,000 psi are shown in Fig. 4. These bars differed from regular production bars in a number of details. From the standpoint of fracture characteristics, the most important differences were that their surfaces were in the rough 'as rolled' condition presumably in the interest of lower cost, and pre-setting was omitted presumably as a step in measuring the value of residual stress induced by this operation.

Bars A, B, C, and E shown in Fig. 4 are seen to have failed by transverse shear, only bar D failed by tension in the manner that would be expected. Transverse failures occurred in most of the specimens because the applied load stressed the bars above their yield strengths and extensive plastic yielding continued throughout each test.

Although the maximum nominal test stresses were somewhat lower than were applied to standard production bars (such as is shown in Fig. 16 Ref. 4) their elastic strengths were exceeded because their unfinished surfaces were decarburized. The decarburized layers were incapable of sustaining their share of the applied loads (Ref. 2), therefore, the stresses in the underlying metal were increased sufficiently to cause extensive plastic creep. The compressive and tensile stress components contributed in substantially equal amounts to the plastic deformation, therefore, after a sufficient number of stress applications the failures resulted from the combined effects of these components to exhaust the capacity of the steel to plastic flow. These specimens are seen to have behaved in the same manner as the modeling clay cylinder shown in Fig. 2(B) of Sept. 1951 article.

The depth of decarburization and subsurface hardness were measured in bars D and E as shown in Table I. In terms of the standing height of the vehicle, Table I also records the extent of plastic yielding of all bars in the group after 5,000, of one bar after 10,000, and of two bars after 20,000 load applications.

A punch press, operated at constant stroke, was used as the fatigue machine. Because plastic yielding continued throughout the tests the applied stress necessarily decreased between periods of load adjustment. Since load restorations were made only after 100, 500, 1,000, 5,000, 10,000, and 20,000 cycles, the average applied stress varied appreciably below that of the specified load.

Magnetic particle inspection, which was applied to each of the five torsion bars prior to fatigue testing, revealed short longitudinal seams in all bars as noted in Table I. In only one

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specimen, bar D, was the character of the fracture dominated by these defects. This bar had, in addition to several short defects, a 5 in. seam near the end of the bar. This long seam acted as a stress raiser for the development of a normal tensile fatigue fracture, the origin of which is indicated in Fig. 4 by a circle. It is probable that, as noted in Table I, the smaller depth of decarburization in bar D was responsible for its greater fatigue durability and its relatively low plastic settling.

Good Reports Require Good Photographs

Photographic records of the fatigue fractures of the subject torsion bars were superior to those usually found in routine laboratory reports, but in only ocasional instances are they adequate for diagnostic purposes. A selected few show sufficient detail to establish definitely the point at which fracture originated and to identify material defects that caused or contributed to the failure. Note, for example the inadequacy of the photograph of bar D of Fig. 4. The report relating to this specimen states that the fracture developed from a longitudinal defect. The point at which the fracture originated can be discerned in the photograph but, because of the angle at which it was taken, no evidence of the defect is seen.

Similarly located fatigue fractures from the same causes are better illustrated in specimens F and G, Fig. 5. These bars differed from the bars shown in Fig. 4 in that their surfaces had been machined to remove decarburized metal and they were also otherwise processed to standard specifications, including prestressing. The bar F was tested at a nominal stress range of 8,500 to 135,500 psi and failed after 87,000 stress cycles. The bar G was tested at a nominal stress range of 22,500 to 150,000 psi and failed after 47,000 stress cycles.

The excellent photographs of bars F and G, Fig. 5, clearly show the points of origin of fatigue fractures as well as the open seams that served as stress raisers to hasten failure. Note that the longitudinal planes of the seams are discolored by heat-treatment and that they are entirely free of characteristic fatigue marking. In both specimens, fractures originate at the junction of the longitudinal fissure and the outer surfaces of the bars. It is also seen that the fatigue fractures advanced from their points of origin at angles of approximately 45 deg to the axes of the bars, that is, the fractures are normal to the tensile components of clockwise torsional loads.

Other details of the fracture surfaces are relatively unimportant because the states of stress in the remaining sections were drastically altered by the advancing fractures. Such unimportant features, however, are often found described in detail and no mention made of the important characteristics. In other instances, clearly defined evidence pointing to the fracture origin and to the contributing causes of fracture is interpreted erroneously.

The metallurgist's report on the fatigue fracture of bar I shown in Fig. 6 states that the fracture originated in the longitudinal defect that appears on the lower edge of the fracture. When discovered by magnetic particle inspection before fatigue testing, this defect was found to be 3.5 in. long. Probably because of prior knowledge of the presence of this defect and because evidence of it appeared in the fracture, the unwarranted conclusion was reached that this defect was the origin of fatigue failure, notwithstanding the well defined nucleus a short distance below the opposite surface of the bar. From the same bar, the section H in Fig. 6 was removed a short distance from the fracture to show another longitudinal seam, this one 2 in. long.

Principal interest in the fracture of bar I, Fig. 6, is that: (1) Its point of origin was not influenced by the presence of at least two major longitudinal defects; (2) the fracture was caused by the tensile components of counter clockwise torsional loads; and (3) the point of greatest effective stress was approximately 0.35 in. below the surface of the bar. Direct evidence is not available, but it is probable that a large inclusion or similar defect served to amplify the stress at the fracture origin.

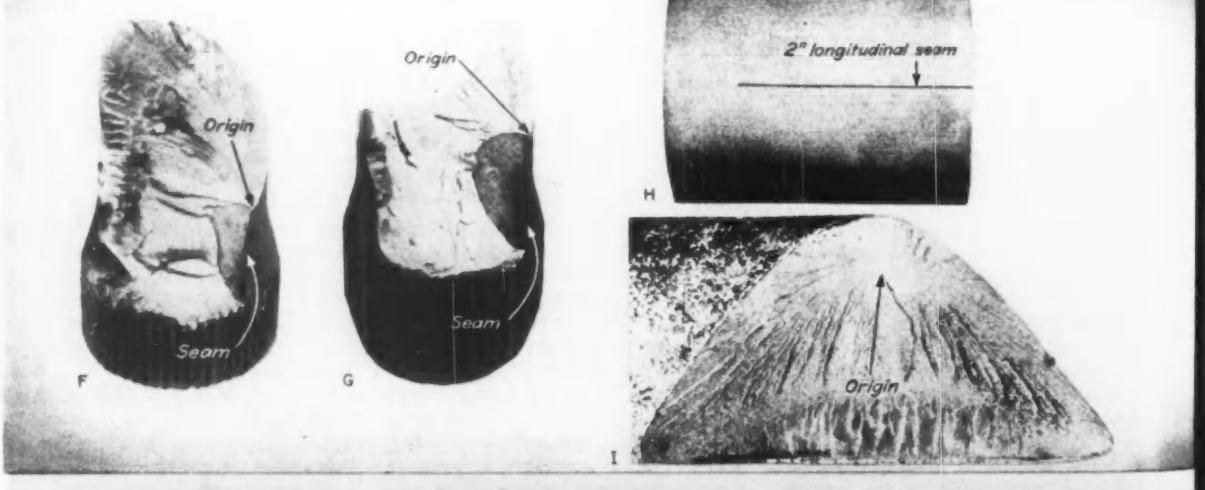

Fig. 5—Tensile fatigue fractures from torsional loads originated in open seams that acted as stress raisers.

Fig. 6—Tensile fatigue fracture that developed independently of major longitudinal defect in opposite side of bar.

Extra Hard Torsion Bars

The fractured specimens L and M of Fig. 7, which failed by tension from repeated clockwise twisting loads, are also of sub-surface origin but their nuclei are not so deep as the nucleus in Fig. 6. No effort seems to have been made to determine the nature of the stress raisers that contributed to these failures. But since the nuclei were between 0.1 and 0.2 in. below the surface, where the nominal prestressing stress was 85 to 90 percent of the nominal surface stress, possible damage during prestressing should be suspected as well as defects originally present in the material.

These specimens were made to standard specifications except in hardness. They were tempered at 750 F to Rockwell C 54, whereas standard production bars were tempered at 850 F to Rockwell C 49. These specimens were therefore more susceptible to damage from plastic yielding during prestressing and to early failure from this damage than bars tempered to greater ductility.

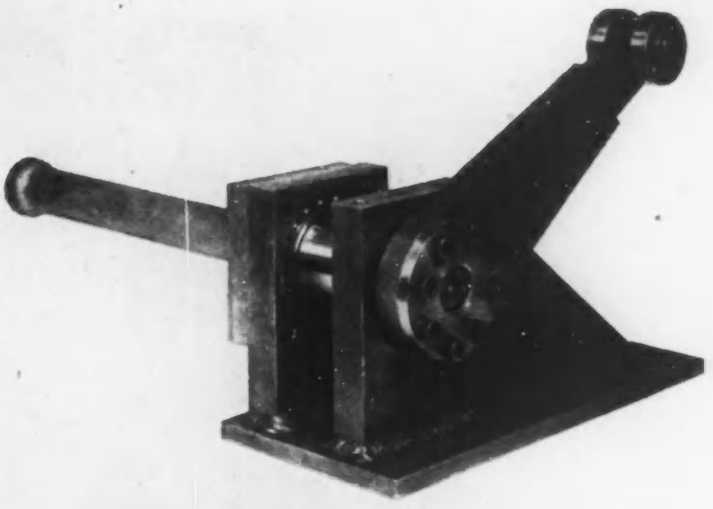

Fig. 8—Type of fixture similar to that used on a punch press for applying torsional loads on bar specimens.

Because fatigue weakness of surfaces increases with brittleness, compressive stresses induced by shot peening and other superficial mechanical operations become more effective in increasing fatigue strength as hardness of the peened steel is increased. Since surface weakness, however, is relatively just as detrimental to the internal surfaces of defects such as inclusions, voids, seams and cracks, as to external surfaces, and since these internal surfaces cannot be reached by peening through hardened highly stressed machine parts must be as free of internal defects as possible.

Deep Prestressing

Prestressing by overloading is the only mechanical process now in use that is capable of inducing favorable residual stresses at depths sufficient to be effective against defective steel. Even this operation is relatively ineffective against any deep defect in very hard steel unless damage from extensive plastic yielding is reduced by prestressing at an elevated temperature.

Torsion bars L and M, Fig. 7, failed after 66 and 310 load applications respectively while being fatigue tested at nominal stresses ranging from 8,500 to 135,500 psi.

The fatigue fracture of torsion bar K, Fig. 7, also originated in sub-surface metal but in this case the stress raisers that hastened failure are prominent in the photograph. This specimen was not only afflicted with a longitudinal seam but a transverse defect is also in evidence. Characteristic fatigue markings have their origins at the junction of the 45 deg plane of the tensile fatigue fracture with the 90 and 0 deg planes of the two defects.

This longitudinal seam, like the same defects in other specimens, was no doubt formed during rolling of the bars at the steel mill. The transverse defect could be, and probably was, a result of straightening after heat-treatment. The original report does not venture an explanation.

The bar was made to standard specifications except that it was given a second shot peening after pre-setting. Additional peening could not, however, have affected its fatigue strength because the origin of the failure, being sub-surface, was out of reach of the shot.

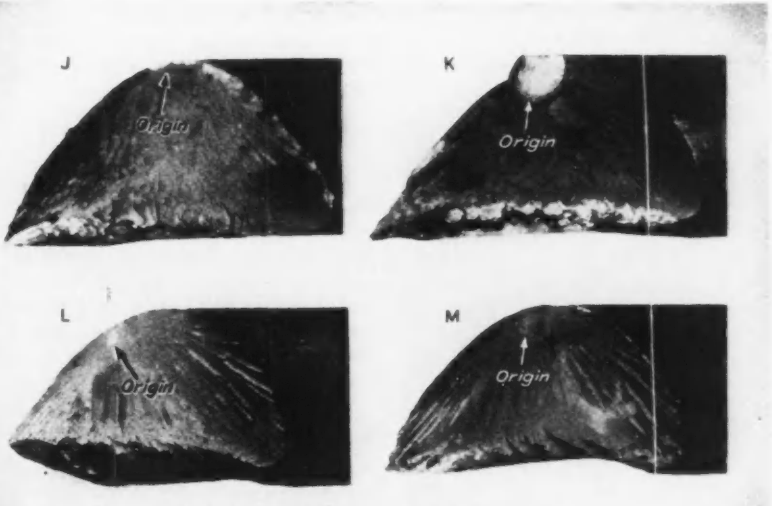

Fig. 7—Tensile fatigue fractures in extra hard torsion bars. Specimens failed under torsional loads. These failures originated in various sub-surface defects.

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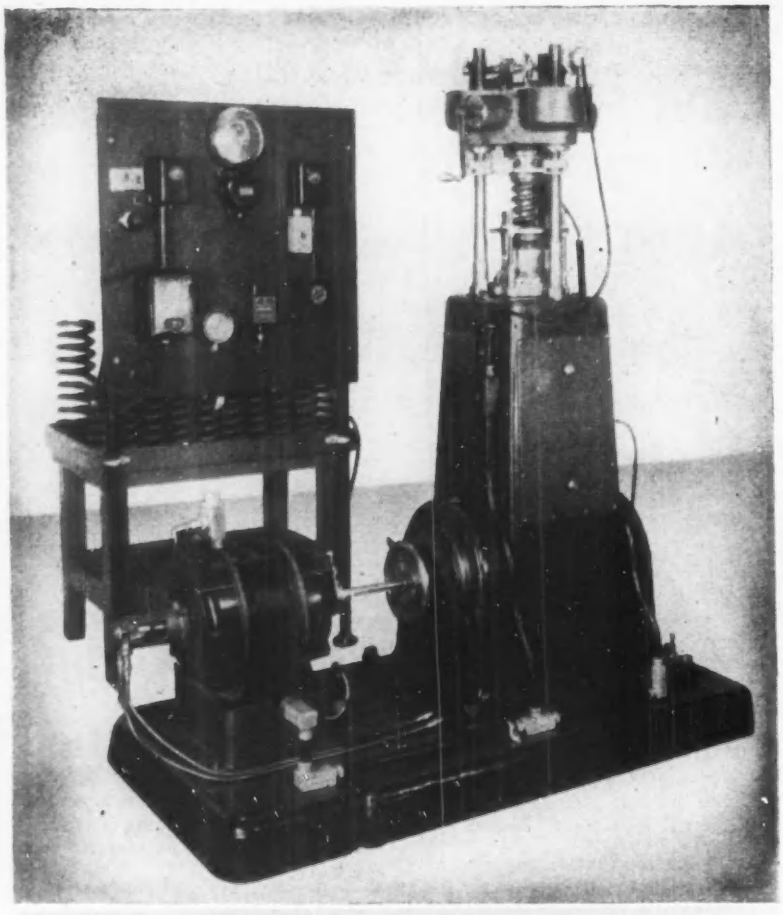

Fig. 9—Resonance type spring testing machine having a set speed of 1,200 cycles per second. As here shown, the coil spring mounted in the head of the machine is under test to determine fatigue life. A special fixture for loading bars in torsion can be installed in machine head.

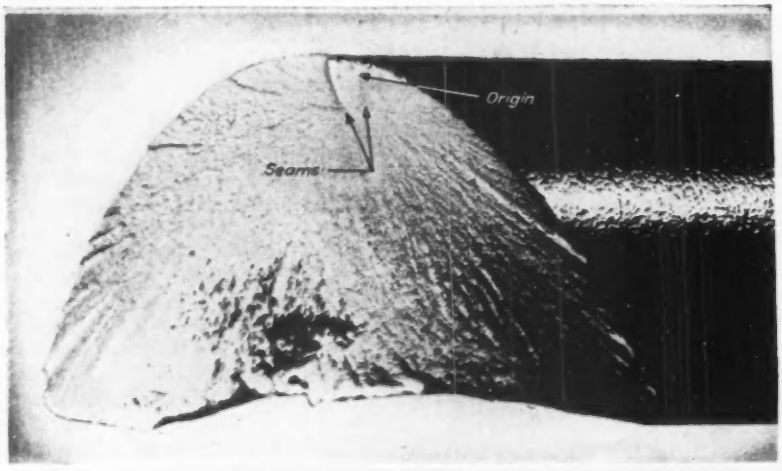

Fig. 10—Tensile fatigue failure from repeated clockwise torsion loads has its origin below surface between short seams. Processing included shot peening followed by prestressing.

Considering the severity of the stress raisers the durability of the specimen was good. It failed after 81,400 cycles at nominal stress ranging from 8,500 to 135,500 psi.

The original report on the specimen J, Fig. 7, states that the failure is of sub-surface origin, but the photograph does not show details beyond the fact that the fracture advanced at a 45 deg angle to the bar axis and downward from the top. This bar failed after 23,600 cycles at the same nominal stress range as was applied to the three specimens K, L and M. Its short life supports the original statement that failure originated below the surface, presumably in a relatively large defect.

Photographic Details Important

The photograph Fig. 10, showing the fatigue fractured section of one of a group of four torsion springs, is so sharp in all details that the point of fracture origin is clearly seen to be a short distance (0.04 in.) below the upper surface between two short longitudinal seams. Crack width was confined to the narrow space (0.13 in.) between the two seams until its inward growth on a 45 deg plane exceeded the depth of the seams (0.22 in.) after which it spread in all directions.

This bar was made from X-9165 steel heat-treated to a hardness in the range of Rockwell C 47-49. Processing included shot peening followed by prestressing. Examination indicated the presence of longitudinal defects with nonmetallic inclusions in all bars of the group. The bar illustrated was fatigue tested by applying unidirectional loads at nominal stress ranging from zero to 137,000 psi. Failure occurred after 30,000 stress applications.

Torsional Fatigue Failures Are Tensile Failures

Military vehicle torsion spring fatigue fractures have been discussed at considerable length because they show that, in spite of inherent planes of weakness, torsional fatigue failures are caused by and develop normal to the tensile component of the applied stress.

REFERENCES

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3. J. O. Almen—Kent's "Mechanical Engineers Handbook", Twelfth edition, Design and Production Volume, p. 20-40 to 20-48 inc.
4. J. O. Almen—"Torsional Fatigue Failures", *PRODUCT ENGINEERING*, September 1951, p. 167.

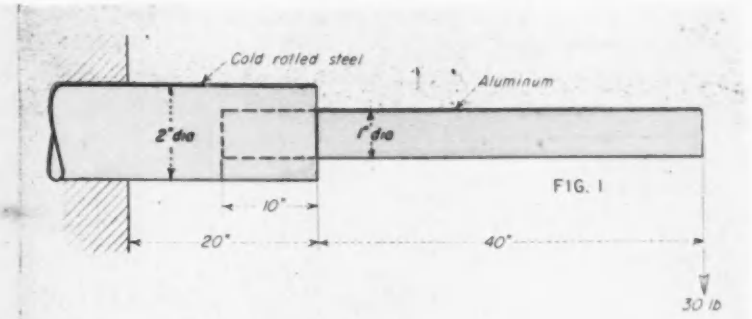

FIG. 1

Fig. 1—Three-element cantilever beam has a large-diameter section made of cold rolled steel and a small-diameter section of aluminum. The latter is, in effect, a secondary cantilever beam supported by the primary steel beam. The combination section between the beams necessitates special computations when determining the deflection at the right end.

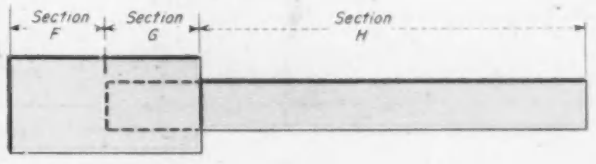

FIG. 2

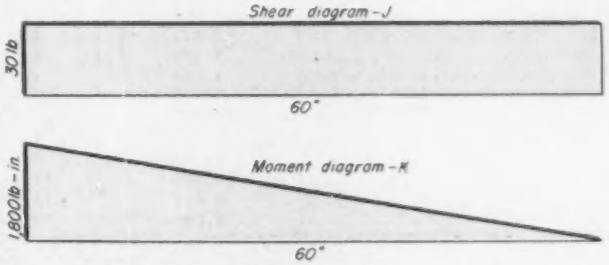

Fig. 2—Moment diagram *K* for cantilever beam is obtained by integrating shear diagram *J*, resulting in magnitude of actual bending moment at any point. If beam were of uniform section and material throughout, calculation of deflection at right end would be simple matter of taking moment of the moment area and substituting in basic deflection formula.

Design of Coupled Overhung Shafts

If the sections of a coupled shaft are made of dissimilar materials and/or have different diameters, calculation of critical speeds becomes a complex procedure. Graphical-mathematical method described herein simplifies this task.

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WHEN VERTICAL SHAFTS ARE DRIVEN through speed reducers such as a gear motor or output shaft worm gear, the problem of designing for critical frequency is complicated by two factors. The first of these arises from the fact that the shaft extension of the geared reducer and the shaft it drives are usually of different diameters. The second complication results when the reducer shaft and driven shaft are made of unlike materials that have different physical characteristics. The analysis and solution of a problem involving either of these factors or a combination of both, is essentially the same as that of a member of uniform diameter. However, allowance must be made for the variation in shaft size, the change in rate of elasticity and the consequent increase or decrease in the flexibility of the shaft as a whole.

The article "Critical Speeds of Overhung Shafts" (PRODUCT ENGINEERING, December, 1950) states that the critical frequency of a rotating shaft can be determined by virtue of the relationship between such frequency and the static deflection for weight loads equal to those of the rotating masses. The effect of a change in flexibility, or a change in

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Table I—Constants for Shaft Materials

Material	$E/10^6$	Wt per cu in., lb
Cold-rolled Steel	29.0	0.284
Stainless Steel	28.6	0.286
Nickel	30.0	0.320
Monel	26.0	0.318
Phos. Bronze	16.0	0.314
Aluminum	10.0	0.098

Table II—Shaft Data

Diameter, in.	Wt per inch of length, lb (cold rolled steel)	Moment of inertia, I
3/4	0.125	0.016
1	0.220	0.049
1 1/4	0.350	0.120
1 1/2	0.500	0.249
1 3/4	0.680	0.460
2	0.890	0.785
2 1/4	1.130	1.258
2 1/2	1.390	1.918
2 3/4	1.680	2.807
3	2.000	3.976
3 1/4	2.350	5.477
3 1/2	2.720	7.366
4	3.560	12.566
4 1/4	4.010	16.015
4 1/2	4.500	20.129

the elastic curve of a beam, caused by variations in the material characteristics and/or the cross section, can be checked by using the so-called conjugate beam method of determining static deflections. This method is based upon the fact that the deflection of a beam is equal to the moment of the moment area of the loading divided by the modulus of elasticity and the plane moment of inertia of the beam cross section. Expressed as a formula, deflection, y, in inches, is

$$y = \frac{M_m}{E\,I} \qquad (1)$$

where M_m represents the moment of the area of the moment diagram in pound-inches cubed, E is the modulus of elasticity of the material in pounds per square inch, and I is the plane moment of inertia, or second moment, of the cross sectional area in inches to the fourth power.

Referring to Eq (1), whenever the modulus E, the moment I or both are variable, it is possible and feasible to account for this variation by suitable changes in the moment M_m. In the method discussed here, the product EI is considered constant and the moment M_m corresponding to a reduction in beam cross section is artificially increased by a factor based upon the ratio of the product EI of the two sections. The folowing example illustrates this procedure.

EXAMPLE 1: The cantilever beam in Fig. 1 consists of 2-in. dia section F made of cold rolled steel; intermediate section G, which has a tubular steel outer member of 2-in. OD and an aluminum core of 1-in. dia; and 1-in. dia section H made of aluminum. Disregarding the weight of the beam itself, what is the deflection at the right end?

SOLUTION: The shear and moment diagrams for the beam are shown in Fig. 2. The moment diagram K is obtained by integrating shear diagram J, which gives the magnitude of the actual bending moment at any point along the beam. The maximum value is at the support and is equal to 1,800 lb-in. If the beam were of uniform section and material throughout its length—2-in. diameter cold-rolled steel, for example—the deflection at the right end could be obtained by taking the moment of the moment area and substituting in Eq (1) as follows:

Area of K is

$1{,}800 \times 60/2 = 54{,}000$ lb-in.^{2}

Moment arm of area K with respect to right end is

$2/3 \times 60 = 40$ in.

Moment of moment area is

$54{,}000 \times 40 = 2.16 \times 10^6$ lb-in.^{3}

From Table 1, the modulus E for cold-rolled steel is 29 x 10^6 and the value of I for a 2-in. shaft from Table II is 0.785. The deflection is then

$$y = \frac{2.16 \times 10^6}{29 \times 10^6 \times 0.785} = 0.0949 \text{ in.}$$

The smaller the diameter and lower the elastic modulus throughout section H, the greater will be the deflection at the end. This can be taken into account by artificially increasing the area of the moment diagram to compensate for the decrease in E and I throughout the length of section H. Applying this to the three-section beam under consideration, the first step in solving for the deflection is to compute the EI products (using Tables I and II) for each section.

Sec. F: $EI = 29 \times 10^6 \times 0.785 = 22.77 \times 10^6$

Sec. H: $EI = 10 \times 10^6 \times 0.049 = 0.49 \times 10^6$

Sect. G (steel shaft): $EI = 29 \times 10^6 \times (0.785 - 0.049) = 21.34 \times 10^6$

Sect. G (total): $EI = (21.34 + 0.49)\ 10^6 = 21.83 \times 10^6$

The ratios R between the product EI for sections G and H with respect to F are:

$R_{FG} = 22.77/21.83 = 1.042$
$R_{FH} = 22.77/0.49 = 46.45$

If the areas of the moment diagram K under the respective sections are multiplied by the EI ratio for each section, the resulting MR diagram will take the form shown in Fig. 3. This diagram indicates that the area ead is actually the moment diagram (K in Fig. 2); the area $gfhj$ represents the artificial increase in the moment area in section G to compensate for the decrease in the product EI in that section; and the area khd represents the artificial increase in the moment area in section H to compensate for its decrease in the product EI in that section. The moments of these moment diagrams are:

For area ead:

$ea = 1{,}800$ lb-in.; $ad = 60$ in.

Area of ead is

$1{,}800 \times 60/2 = 54{,}000$ lb-in.^{2}

Moment arm of area ead is

$2/3 \times 60 = 40$ in.

Moment of area ead is

$54{,}000 \times 40 = 2.16 \times 10^6$ lb-in.^{3}

For area gfd

$gf = gb - fb = 1{,}500\ (1.042) - 1{,}500 = 63.0$

$bd = 50$ in.

Area of *gfd* is

$63.0 \times 50/2 = 1575$ lb-in.²

Moment arm of area *gfd* is

$2/3 \times 50 = 33.33$ in.

Moment of area *gfd* is

$1,575 \times 33.33 = 0.053 \times 10^6$ lb-in.³

For area *kjd*

$kf = kc - jc = 1,200\ (46.45) - 1,200\ (1.042) - 54,500$ lb-in.²

$cd = 40$ in.

Area of *kjd* is

$54,500 \times 40/2 = 1,090,000$ lb-in.²

Moment arm of area *kjd* is

$2/3 \times 40 = 26.67$ in.

Moment of area *kjd* is

$1,090,000 \times 26.67 = 29.1 \times 10^6$ lb-in.³

Total moment of moment area *eadkjgf* is

$(2.16 + 0.053 + 29.1)\ 10^6 = 32.31 \times 10^6$

When substituting this last value in Eq (1), the *EI* value for section *F* must be used because the *MR* values for sections *G* and *H* have been computed with reference to this product. Therefore

$$y = \frac{32.31 \times 10^6}{29 \times 10^6 \times 0.785} = 1.42 \text{ in.}$$

This computation for the deflection does not take into account the weights of the different sections of the beam, which are generally necessary when the method is used for determining the critical frequency of a shaft. In such instances, the approach to the problem can be considerably simplified by developing suitable equations for the great majority of applications, leaving the more detailed analysis for use in special applications.

A common type of vertical agitator shaft construction is shown in Fig. 4. The shaft *A* is connected to the lower end of the output shaft *S* of a vertical worm gear reducer by the rigid two-part flanged coupling, the halves of which are shrunk on to the shafts and bolted together.

Diagram *C* in Fig. 5 shows the portion of the assembly that is below the centerline of the lower reducer bearing. For the sake of simplicity, it is assumed that the diameter of the reducer shaft is constant and is equal to the diameter of the output end *D*. It is further assumed that the portion of the agitator shaft *A* inside the lower half of the coupling can be treated as though its diameter is also equal to *D*. Both of these assumptions are on the side of safety, particularly the latter, because the reinforcing effect of the coupling flange and hub materially decreases the flexibility of the combined shafts. Diagram *F* in Fig. 5 shows the moment diagram for the concentrated load *W*, with a modification for the effect of the change in the *EI* product for diameter *d*. Diagram *G* shows a similar arrangement for uniform loading representing the weight of the lower shaft *A*. Quantity *X* represents the length of this shaft.

In the analysis that follows, the weight of the shaft is considered uniform and equivalent to the weight of the agitator shaft only throughout distance *L* in Fig. 4 from the centerline of the lower bearing to the centerline of the load. This analysis of uniform load disregards the small difference in weight between the reducer output shaft and the agitator shaft.

Considering the effect of load *W* in Fig. 5, the maximum moment represented by the ordinate *ce* is *WL*. The length of the moment diagram is *ac* or *L* so that the diagram area becomes $WL^2/2$. The quantity *q* is the centroidal distance for area *ace* and is equal to $2L/3$. The moment of area *ace* is therefore

$$(WL^2/2)\ (2L/3) = WL^3/3$$

Let *R* represent the ratio between *EI* values for the reducer shaft *S* of diameter *D* and the agitator shaft *A* of diameter *d*:

$$R = \frac{E_D I_D}{E_A I_A} \qquad (2)$$

In Fig. 5, the moment diagram for shaft *A* alone has length *ab* or *X*, and maximum ordinate *bj* or *WX*. When this ordinate is increased by ratio *R*, its length becomes *bg* and is designated by quality *RWX*. Then

$$fg = bg - bf = RWX - WX = (R - 1)\ WX$$

Area *afg* is $1/2\ (R - 1)\ (WX)\ X$ and centroidal distance *r* for this area is $2X/3$. Thus the moment of the area is

$$(R-1)\left(\frac{WX^2}{2}\right)\left(\frac{2X}{3}\right) = (R-1)\frac{WX^3}{3}$$

Moment of entire area *acefg* is

$$\frac{WL^3}{3} + (R-1)\frac{WX^3}{3} = \frac{W}{3}\left[L^3 + X^3(R-1)\right] \qquad (3)$$

For the uniform load shown in diagram *G*, Fig. 5, *u* equals the total weight for a shaft of length *L* and diameter *d*, and the moment diagram is parabolic in form (curve *hm*).

The maximum ordinate *km* is equivalent to $uL/2$ and moment diagram length *hk* is *L*. Area of moment diagram *hkm* is therefore

$$\frac{L}{3}\left(\frac{uL}{2}\right) = \frac{uL^2}{6}$$

When this expression is multiplied by centroidal distance *t*, which is $3L/4$, moment of area *hkm* is

$$\frac{uL^2}{6}\left(\frac{3L}{4}\right) = \frac{uL^3}{8}$$

Considering area *hnp* with moment diagram length *X*, maximum ordinate *pn* is $uX/2$, which, when in-

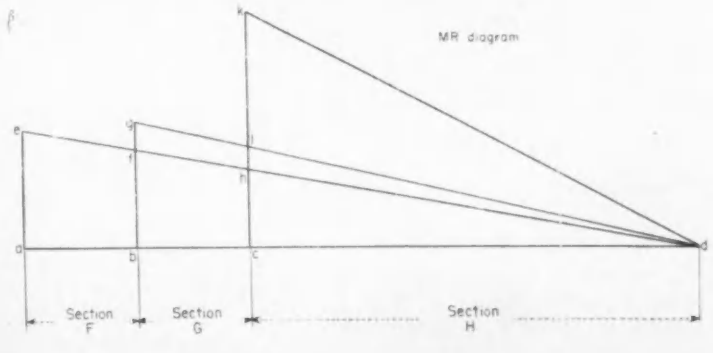

Fig. 3—*MR* diagram for cantilever beam is result of multiplying the *EI* ratios for the three sections of the beam by the respective areas of the moment diagram. Area *ead* is actually moment diagram *K* shown in Fig. 2.

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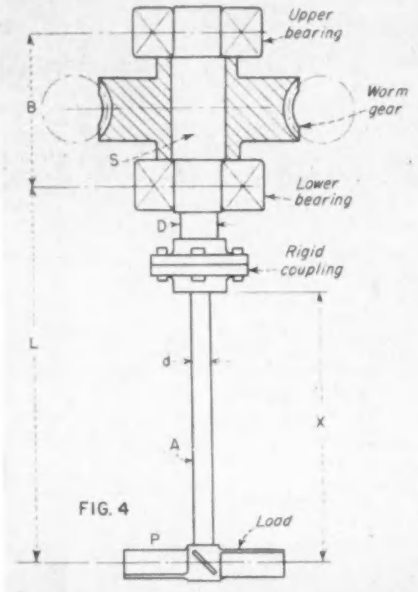

FIG. 4

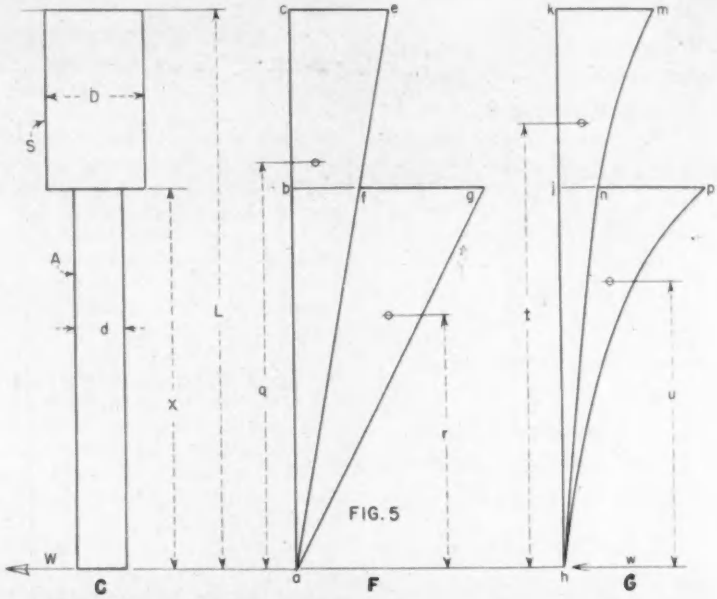

FIG. 5

Fig. 4—Vertical agitator assembly has large-diameter shaft *S* of worm gear reducer connected to small-diameter shaft *A* by rigid coupling.

Fig. 5—Diagram "C" represents portion of agitator assembly below centerline of lower reducer bearing. "F" is moment diagram for concentrated load *W*; "G" is for uniform load *w* representing weight of lower (small diameter) shaft.

creased by ratio R, becomes $RwX/2$. Then

$$np = jp - jn = \frac{RwX}{2} - \frac{wX}{2}$$

$$= (R-1)\frac{wX}{2}$$

The area of the moment diagram is

$$\frac{X}{3}(R-1)\frac{wX}{2} = (R-1)\frac{wX^2}{6}$$

and, taking the centroidal distance u as $3X/4$, the moment of area hnp becomes

$$(R-1)\frac{wX^2}{6}\left(\frac{3X}{4}\right) =$$

$$(R-1)\frac{wX^3}{8}$$

The combined area $hkmnp$ is therefore represented by the expression

$$\frac{w}{8}\left[L^3 + X^3(R-1)\right] \quad (4)$$

and the deflection for the concentrated load W is obtained by substituting Eq (3) in Eq (1)

$$y = \frac{(W/3)\left[L^3 + X^3(R-\tfrac{3}{4})\right]}{EI} \quad (5)$$

and for the uniform load w is

$$y = \frac{(w/8)\left[L^3 + X^3(R-1)\right]}{EI} \quad (6)$$

where R is obtained from Eq (2) and EI is the elasticity-modulus-second-moment product for the shaft of diameter D.

From the preceding article PRODUCT ENGINEERING, December 1950) the critical frequency for a shaft with with a concentrated load W is

$$N_c = 187.7\sqrt{\frac{1}{y}} \quad (7)$$

and for a shaft with a uniform load w is

$$N_w = 234\sqrt{\frac{1}{y}} \quad (8)$$

The critical frequency of a shaft subjected to these two systems of loading is

$$N = \frac{N_c N_w}{\sqrt{N_c^2 + N_w^2}} \quad (9)$$

By substituting Eqs (5) and (6) in Eqs (7) and (8) and combining the critical frequencies thus found in Eq (9), the following expression for operating frequency is obtained

$$N = 325 \times \sqrt{\frac{EI}{(W + 0.236w)\left[L^3 + X^3(R-1)\right]}} \quad (10)$$

But the reducer shaft is supported in bearings as illustrated in Fig 4, making it necessary to modify the critical frequency obtained from Eq (10) by a bearing span factor SF from

$$SF = \sqrt{\frac{L}{L+B}} \quad (11)$$

where, in Fig. 4, L is the overhanging length and B is the bearing spacing, both expressed in inches.

Sample Calculations

EXAMPLE 2: A vertical agitator shaft A, similar to that in Fig. 4, of 3-in. diameter, is rigidly coupled to the lower end of the output shaft of a vertical worm gear reducer. The reducer shaft has a diameter of 4 in. and a bearing span of 15 in. The overhang of the 60-lb impeller is 80 in. and the distance from the centerline of the lower reducer bearing to the lower end of the coupling is 20 in. The agitator shaft and the reducer shaft are made of material equivalent to cold-rolled steel in physical characteristics. The problem is to determine the permissible operating speed of the agitator if the critical frequency is to exceed the operating speed by at least 30 percent.

SOLUTION: L is 80 in., X is 60 in., W is 40 lb, D is 4 in. and d is 3 in. From Table II, I_4 is 12.566 and I_3 is 3.976. From Eq (2)

$$R = \frac{29 \times 10^6 \times 12.566}{29 \times 10^6 \times 3.976} = 3.16$$

From Table II, w is 2 lb per in. times 80 in., or 160 lb. Substituting in Eq (10).

$$N = 325 \times \sqrt{\frac{29 \times 10^6 \times 12.566}{(40 + 0.236 \times 160)\,[80^3 + 60^3\,(3.16 - 1)]}}$$

$$N = 712$$

The bearing span factor from Eq (11) is

$$SF = \sqrt{80/(80 + 15)} = 0.918$$

The critical frequency, therefore, is

$$N_c = 712\ (0.918) = 654 \text{ rpm}$$

The critical frequency must be at least 130 percent of the operating frequency N_o which thus becomes

$$N_o = \frac{654}{1.3} = 503 \text{ rpm}$$

EXAMPLE 3: The chemical composition of the mixture in which the impeller of Example 2 is operating necessitates the use of a stainless steel impeller and shaft. To achieve an economical design, the agitator shaft A is to be made of stainless steel tubing having a $3\frac{1}{4}$-in. OD and a $2\frac{3}{4}$-in. ID. The problem is to determine whether this change in design will seriously affect the critical frequency.

SOLUTION: Moment of inertia L_t for a tubular shaft having the above dimensions is equal to the difference of the two moments of inertia as listed in Table II

$$I_t = I_{3.25} - I_{2.75} = 5.477 - 2.807 = 2.670$$

Table I shows E for stainless steel as 28.6×10^6 and for cold-rolled steel as 29×10^6, so that Eq (2) gives

$$R = \frac{29 \times 10^6 \times 12.566}{28.6 \times 10^6 \times 2.670} = 4.77$$

The weight W of the impeller, from the ratio of the unit weights of the two materials, is

$$40\left(\frac{0.286}{0.284}\right) = 40.3 \text{ lb}$$

and weight w of the stainless steel tube, from Tables I and II, is

$$(2.35 - 1.68)\left(\frac{0.286}{0.284}\right)80 = 54 \text{ lb}$$

From Eq (10)

$$N = 325 \times \sqrt{\frac{29 \times 10^6 \times 12.566}{(40.3 + 0.236 \times 54)\,[80^3 + 60^3\,(4.77 - 1)]}}$$

$$N = 740 \text{ rpm}$$

The operating frequency then becomes

$$N_o = \frac{740 \times 0.918}{1.30} = 523 \text{ rpm}$$

This result indicates that a tubular shaft can safely be used because the permissible operating frequency is higher than that of slightly smaller outer diameter. The decreased weight of a tubular shaft as compared to a solid shaft is equal to

$$[2.0\left(\frac{0.286}{0.284}\right)80] - 54 = 107 \text{ lb}$$

Tubular shafts can therefore be used in preference to solid shafts whenever the economy resulting from a decrease in weight more than offsets the increased pound-price cost of tubing of similar material.

EXAMPLE 4: The chemical composition of the agitated mixture requires the use of a phosphor bronze impeller and agitator shaft. Problem is to determine the permissible operating frequency if bronze tubing of $3\frac{1}{2}$ in. OD and $2\frac{3}{4}$ in. ID is used for the agitator shaft.

SOLUTION: From Table II

$$I_t = I_{3.50} - I_{2.75} = 7.366 - 2.807 = 4.559$$

and from Table I, E for bronze is 16×10^6. Then,

$$R = \frac{29 \times 10^6 \times 12.566}{16 \times 10^6 \times 4.559} = 5.0$$

The weight W of a bronze impeller, corresponding to a steel impeller of the same size, is

$$60\left(\frac{0.314}{0.284}\right) = 66.3 \text{ lb}$$

and weight w of a bronze tube is

$$(2.72 - 1.68)\left(\frac{0.314}{0.284}\right) = 80 = 92 \text{ lb}$$

From Eq (10)

$$N = 325 \times \sqrt{\frac{29 \times 10^6 \times 12.566}{(66.3 + 0.236 \times 92)\,[80^3 + 60^3\,(5.0 - 1)]}}$$

$$N = 564$$

$$N_o = \frac{564 \times 0.918}{1.30} = 398 \text{ rpm}$$

This result shows that even a larger size of tubing does not compensate for the increased weight and flexibility of the material used. For the sake of interest, the actual size of tubular bronze shaft required is one having a $4\frac{1}{2}$-in. OD and a $3\frac{1}{2}$-in. ID. Computations as above result in a permissible operating frequency of 535 rpm, which compares favorably with the speed of 503 rpm in Example 2 above.

GE Predicts Germanium Will Miniaturize Electronic Components

DEVELOPMENT OF TINY TRANSISTORS made of silver-like germanium promises to have an effect on electronic components comparable to the development of the vacuum tube. General Electric Corporation's electronic division stated that a radio of hearing aid size capable of running indefinitely on one set of batteries is already within development sight.

Transistors, along with a second product called diodes, are made of tiny pellets of germanium smaller than the head of a match. Smaller, more efficient, longer-lasting, and cheaper to operate, the transistors and diodes may eventually replace all vacuum tubes with the exception of high frequency tubes and picture tubes for which germanium products are not suitable substitutes.

Germanium is an extremely hard and brittle metal that is recovered as a by-product in the smelting and refining of zinc ores. Approximately twenty freight cars of zinc ore are required to recover one pound of germanium.

Transistors and diodes require the metal in a practically pure state; less than one part per hundred billion of some impurities have an observable effect. Germanium purified to this extent is comparable in cost to gold, but the small amount used in the electronic components makes the material cost low relative to fabrication costs.

Properties of germanium that make it valuable arise from the fact that it is a semi-conductor—midway in its electrical properties between such metals as copper and such insulators as glass. Its ability to conduct electricity depends on certain impurities injected into layers of germanium.

One possible use of the miniature components is in the giant digital computers. Now requiring several thousand vacuum tubes and occupying a large volume of space, the computers could conceivably be reduced small enough and become reliable enough with the use of germanium to apply to everyday business and industrial problems. Another important use will be in airborne equipment, where space and weight are at a premium.

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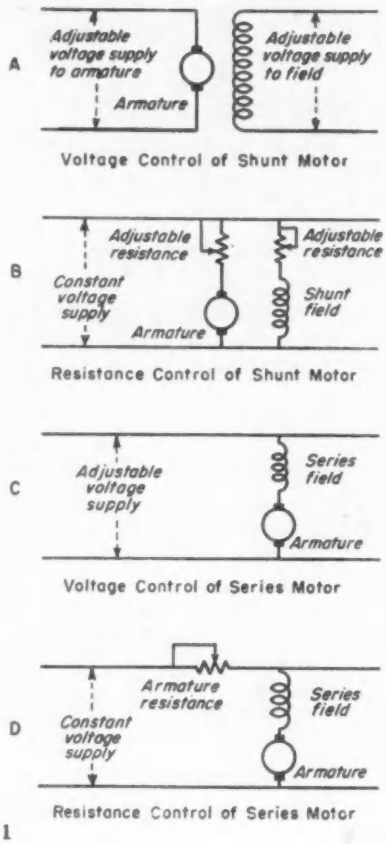

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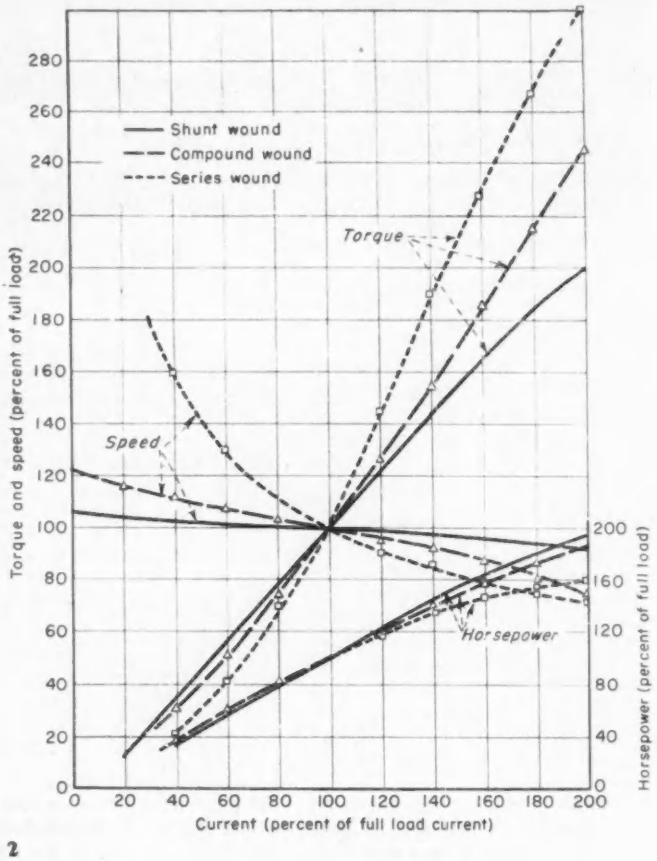


2

Adjustable Speed Characteristics

Although the distribution of d-c power has virtually ceased, the use of d-c motors is increasing. Ease of speed control is the reason. A review of the performance of the three common d-c motors as their speeds are adjusted.

THE DISTINGUISHING FEATURES of all d-c motors are the commutator and brushes, which are used to carry current to the windings of the rotating armature. Torque is produced by the interaction of the magnetic fields set up by armature current with those established by the stationary field windings. Torque characteristics are of course of importance to any user of motors. But in the case of d-c motors, speed characteristics are usually of more vital interest. The majority of new applications for such motors call for adjustable speeds.

When a current-carrying conductor enters a magnetic field, a force acts on that conductor, tending to drive it in a definite direction. This, briefly, is the phenomenon of motor action. At the same time, a voltage is generated in the conductor as it moves through the field. The direction of this voltage is opposite to that of the applied voltage, so that it is termed back or counter electromotive force.

Back emf is a prominent term in the relationship

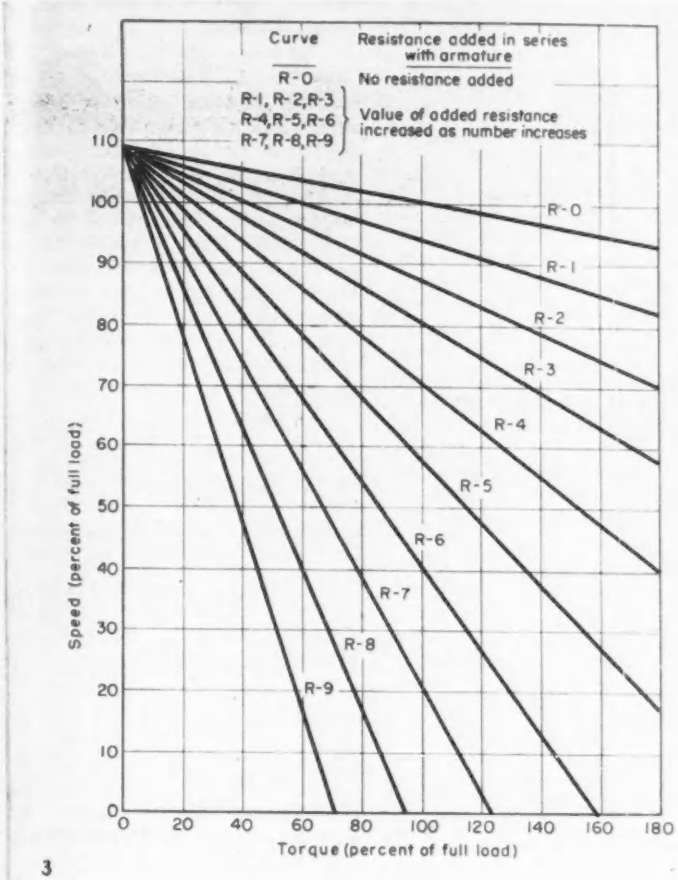
$$V = E + I_a R_a = K \phi S + I_a R_a \quad (1)$$

where V = applied voltage
K = a constant
E = back emf
I_a = armature current
R_a = armature circuit resistance
S = armature speed (rpm)
ϕ = field flux

Transposing the terms of Eq (1)

$$S = \frac{V - I_a R_a}{K \phi} \quad (2)$$

This is the equation for the speed of a d-c motor. On the basis of this formula, it can be seen that there are three means by which motor speed can be adjusted. If a motor is operating under constant load, its speed can be



3

1. Means of adjusting speeds of d-c motors. Motor speed is related to three variables — applied voltage, armature resistance, and field flux. A change in one or more of these three factors produces a corresponding change in the speed of the motor.

2. Comparison of performance curves of the three main types of d-c motors. Note that the speed curve for the shunt wound motor is substantially flat. It is classified as a constant speed device. The speed curve for the series wound motor shows a great drop in speed with added load — it is classified as a variable speed device. The speed curve for the compound wound motor is not as flat as the speed curve for the shunt wound motor. But the compound wound motor has less drop in speed with increase in load compared to the speed change for the series motor.

3. Effect of changing the resistance in the armature circuit on the speed and torque of the shunt wound motor. Readings were taken with rated voltage on the shunt field.

# of d-c Motors

F. A. LIST
Westinghouse Electric Corporation

changed by varying the field strength, the applied voltage or the armature circuit resistance.

The operating characteristics of a d-c motor are determined by the relative arrangement of the armature and field coils in the electrical circuit. The variety of circuits possible has resulted in the availability of many different types of d-c motors. But, in the integral horsepower sizes, only three of these are in common use. The popular types are: (1) shunt wound or stabilized shunt wound; (2) series wound; and, (3) compound wound.

Shunt Wound Motor

In a shunt wound motor, the field winding is in parallel with the armature coils. Thus, the field current is independent of changes in armature current. Since the flux set up by the field poles is constant and because speed is proportional (inversely) to field flux, it might be expected that the shunt motor is essentially a constant speed device. However, in modern shunt wound motors having low armature resistance and small air gaps, there is actually an increase in speed with rising load. This is explained by the fact that when additional load is imposed on the motor, the armature current becomes greater. The additional flux set up by the armature current opposes the field flux in such a way that there is a net decrease in the flux threading the armature coils. This phenomenon is called armature reaction.

To insure a drop in speed, or at least constant speed with increase in load, it is necessary to add a light series field. The series field, consisting of a few turns of heavy conductor, is wound around the same poles as the shunt field. The flux of the series field is proportional to load current and is arranged so as to counteract any changes in armature flux caused by load variations. A d-c machine with such a combination of series and shunt fields is known as a stabilized shunt wound motor.

The curves in Fig. 2 include the performance curves for a typical shunt wound motor. It can be seen that the change in speed from no load to full load is small, so that speed regulation is good. The shunt motor is classified as a constant speed motor. This means that for any given applied voltage, operating speed remains sub-

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stantially the same despite variations in load.

When started at rated voltage, the shunt wound motor draws high currents. These are objectionable because of commutation difficulties as well as the drain on the power supply. Therefore, reduced voltage starting is recommended. If the supply voltage is not adjustable, reduced voltage starting can be accomplished by applying full voltage to the shunt field and adding resistance in the armature circuit.

Shunt wound motors are used on constant speed applications when a-c power is not available, on applications requiring a great range of speed control with good efficiency, and on applications where the speed-torque characteristic must be controlled accurately over a great range of speed and torque. Typical shunt motor driven devices include machine tools, fans, blowers and centrifugal pumps.

Speed Control of Shunt Motor

The speed of a shunt motor can be controlled by inserting rheostats in the armature and field circuits. Where it is desired to obtain a range of speed adjustment that is below the rated speed of the motor, armature resistance control is employed. If the load requires a constant torque from the motor, the speed of the motor will drop as resistance is added in the armature circuit. This can be explained by study of the torque formula and the speed formula.

$$T = K' \phi I_a \quad (3)$$

where T = Torque
K' = A constant
$*\phi$ = Field flux
I_a = Armature current

and $$S = \frac{V - I_a R_a}{K \phi} \quad (2)$$

From the torque formula, we see that to get constant torque with a constant field flux, the armature current must be constant. If the armature current is constant, the value of $I_a R_a$ increases as R_a increases. We, therefore, see from the speed formula that the speed is decreased as the value of R_a is increased when constant torque is maintained. In Fig. 3 is given a family of curves illustrating the effect of changes in armature circuit resistance on the speed-torque characteristic of the motor.

A second method of adjusting the speed of a shunt wound motor to values below rated speed involves the control of the voltage impressed on the armature. Rated voltage is applied to the field circuit. A set of speed-torque curves observed with this type of control is plotted in Fig. 4.

A comparison of the curves for armature resistance control, Fig. 3, and the curves for armature voltage control, Fig. 4, will show that the speed regulation

$$\frac{\text{no load speed} - \text{full load speed}}{\text{full load speed}}$$

for the armature resistance control scheme is much greater than the speed regulation for the armature voltage control scheme. This can be explained as follows: Let us consider the two schemes on the same motor. In each case, rated voltage is applied to the shunt field. Let us consider that each scheme is applied to give the same torque and speed. From the speed formula, Eq (2), the following speed relationships for the two schemes are obtained:

$$S_{arc} = \frac{V_{supply} - I_{a1} R_{a1}}{K\phi}$$

$$S_{ave} = \frac{V_{reduced} - I_{a2} R_{a2}}{K\phi}$$

S_{arc} = Speed for armature resistance control
S_{ave} = Speed for armature voltage control

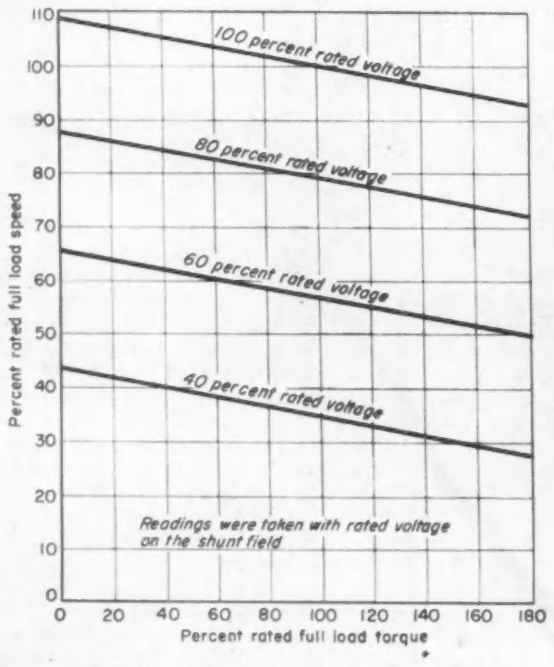
These speeds are the same for a particular torque as previously specified but at no load, the $I_{a1}R_{a1}$ and $I_{a2}R_{a2}$ become very small making

$$S_{arc} = \frac{V_{supply}}{K\phi}$$

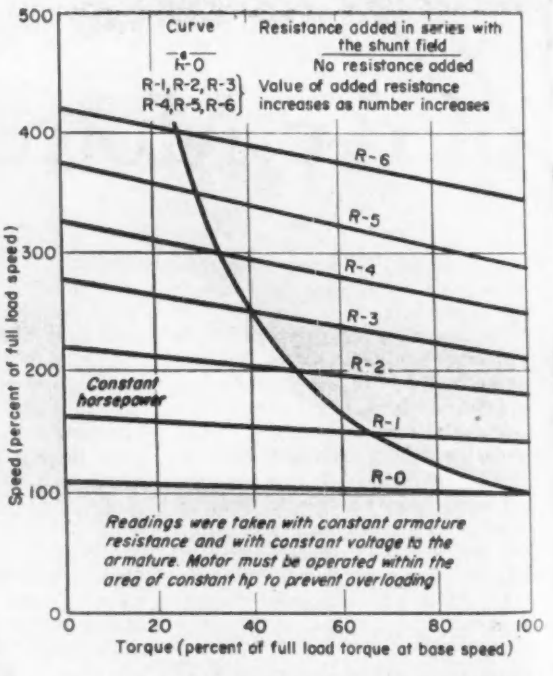
$$S_{ave} = \frac{V_{reduced}}{K\phi}$$

Thus the no load speed of the motor with the armature resistance control is

* Field flux is constant because rated voltage is applied to the field circuit.



4. Effect of changing armature voltage on the speed and torque of the shunt wound motor.



5. Effect of changing resistance in the shunt field circuit on speed and torque of the shunt wound motor.

greater than the no load speed of the motor with armature voltage control.

Generally, the standard shunt wound motor, with armature resistance control or with armature voltage control, can be operated at rated full load torque down to 15 to 20 percent of rated full load speed without "overloading" the motor.

The efficiency of adjustable voltage control is higher than that of the adjustable resistance control. With the latter, there is appreciable power dissipated as heat in the rheostats, especially at the lower speed settings. However, the equipment needed to provide adjustable voltages is costly.

Field Control

By field resistance control, speeds higher than the rated speed of the motor can be obtained. This scheme uses rated voltage on the armature and series resistance in the field circuit. As the resistance in the field circuit is increased, field current and, thus, the established field flux become less. If the load requires a constant torque from the motor, the armature current will vary inversely as the field flux. This can be seen by examining the torque formula

$$T = K' \phi I_a \quad (3)$$

If torque is to be constant and if the field flux is to be decreased such that its new value is ϕ/r, then the armature current must increase to the new value of rI_a

$$T = K' \phi/r \times rI_a = K' \phi I_a$$

The effect of reduced field flux on the speed of the motor driving a load requiring constant torque will be seen by examining the speed formula. The original speed is represented by the equation

$$S_1 = \frac{V - I_a R_a}{K\phi}$$

If the field flux is decreased such that its new value is ϕ/r and the armature current increases to a new value of rI_a (condition for constant torque), the new speed is represented by the equation

$$S_2 = \frac{V - rI_a R_a}{K\phi/r} = \frac{r(V - rI_a R_a)}{K\phi}$$

It is, therefore, seen that if the field flux is reduced, the speed of a shunt wound motor that is driving a load requiring a constant torque will increase.

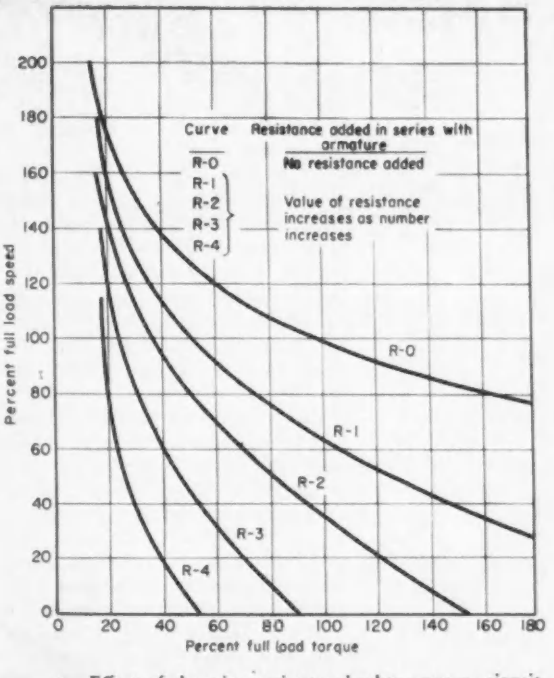
The speed of the standard shunt wound motor can generally be increased to two times rated speed of the motor by this scheme, provided that the maximum allowable speed of the armature is not exceeded. If a speed range of 3 to 1 or more is needed with field control, a special design motor should be used.

The curves of Fig. 5 show the relationship between speed and torque for various values of field resistance. It must be remembered that the maximum permissible horsepower output of any given motor depends on its design and physical proportions and must be kept substantially constant. The shaded portion of Fig. 5 represents the area of constant horsepower and defines the limits of the allowable torque that can be developed at any speed setting. A motor operated beyond this area is overloaded.

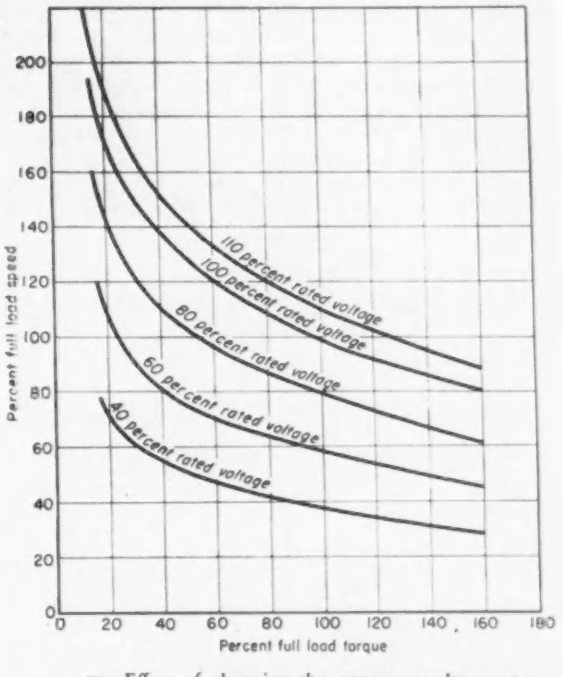
The speed regulation for the various values of field flux are affected by two factors—the armature I_aR_a drop and the armature reaction. Since the motors are rated at constant horsepower, the rated current for all speeds will be about constant. Therefore, the I_aR_a drop will be about constant. The armature reaction will vary depending on the field flux and the degree of saturation in parts of the magnetic circuit. Since this is a variable, the speed regulation will change for various values of field flux.

Series Wound Motor

The series wound motor is similar in construction to the shunt wound motor, except that it has a heavy field winding in series with the armature and it has no parallel or shunt field.



6. Effect of changing resistance in the armature circuit on the speed and torque of a series wound motor.



7. Effect of changing the armature voltage on the speed and torque of a series wound motor.

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From the performance curves in Fig. 1, it is apparent that the speed becomes dangerously high at no load. Therefore, it is necessary that at least some portion of the load be coupled positively to the motor at all times to prevent runaway. The minimum load called for depends on the maximum allowable speed of the armature.

The starting torque of the series motor is great and the inrush current relatively low. Series motors up to 15 hp may be line-started successfully. For larger ratings, reduced voltage or armature resistance control is commonly employed.

Speed fluctuations between light and full load conditions are considerable so this motor is classed as varying speed. Its characteristics make the series wound motor generally suited for widely varying loads such as hoists, cranes, winches, wheel drives (traction motors), and for accelerating high inertia loads.

Speed control of a series motor can be effected by the same means as used for shunt wound machines. For speeds below rated, adjustable terminal voltages or rheostats in series with the armature are provided. The resistance method is a convenient method of control, since it serves also as a means of limiting current inrush during starting. In traction applications, special types of control circuits are often used. In these, two or more motors are connected in series for starting or to obtain low speeds. Then, the motors are switched over to parallel operation for the higher range of speeds.

The effects of both adjustable voltage and armature resistance on the speed and torque characteristics of the series wound motor are shown in Figs. 6 and 7. If the series wound motor is driving a load requiring constant torque from the motor, the speed will decrease if resistance is added in the armature circuit or if the voltage supplied to the armature is decreased. This is similar to action in the shunt wound motor except the curves for the series motor are of the catenary variety in contrast to the straight line relationships for the shunt wound motor. This is because the armature current and the field flux are interrelated. Actually, for the regions of operation where the field structure is unsaturated, torque is proportional to the square of the armature current.

Speeds higher than rated can be obtained by weakening the series field. This can be done by shunting a low resistance across the series winding or short circuiting some of the turns. This is seldom done due to the high values of speed occurring with light loads. Also during transient conditions, such as a high torque pulse requirement from the motor, all of the current will tend to go through the shunt because of its relatively low reactance—the series field has quite a high reactance. This will tend to make the armature current excessively high giving commutation troubles.

Compound Wound Motor

The compound wound motor is similar to the stabilized shunt wound motor, except that the series field is heavier to produce a greater speed change from no load to full load. Typical performance curves for this type of motor are given in Fig. 2. It is seen that the speed regulation for this motor is higher than that for the shunt wound motor and less than that for the series wound motor. In Table I is listed the maximum speed regulation to be expected from a compound wound motor.

Since the compound motor has both shunt and series fields, it provides a combination of some of the benefits offered by the other motors. The compound motor has relatively good speed regulation at rated load, as does the shunt wound motor, and high starting torque with relatively low starting current, as does the series wound motor. Compound wound motors larger than 5 hp are not generally line started. Reduced voltage or armature resistance starting control is recommended.

Compound wound motors are applied where a reasonably constant speed is required and where the load pulsates or heavy overloads are encountered. Punch presses, jaw crushers, compressors, reciprocating pumps, winding machines, and conveyors are driven satisfactorily by compound motors.

Speed Regulation

Speed regulation which is an indication of the amount of motor speed change with varying load, is arrived at by the relationship:

$$\% \text{ Speed Regulation} = \frac{\text{No Load Speed} - \text{Full Load Speed}}{\text{Full Load Speed}} \times 100$$

Compound wound motors are selected and used because of their inherent speed regulation—no external speed control is used save for starting. If the various schemes of adjusting the speed of d-c motors are used on the compound wound motor, the speed regulation becomes poor, thus giving characteristics unwanted on loads requiring the characteristics of a compound wound motor.

Regulation values listed in Table I are the maximum variations in speed from full load to no load allowable under NEMA standards. Readings are taken with motor at operating temperature.

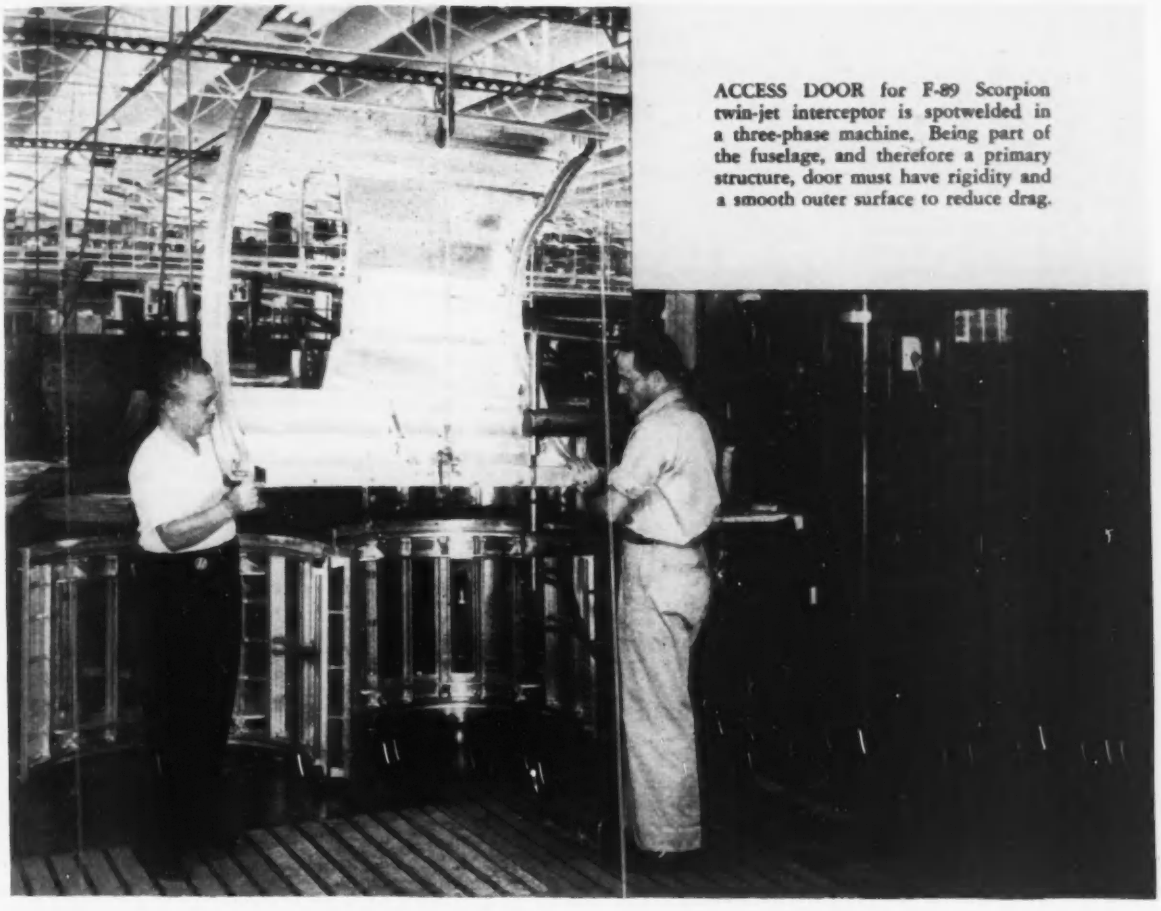
The change in speed of a shunt motor with increasing load is relatively small so that regulation is good. However, when resistance is added in series with the armature, regulation is affected adversely. This poorer regulation is another disadvantage that accompanies the use of the armature resistance method of speed control. Regulation is not as much affected when voltage adjustment is employed.

The speed regulation of a series motor is basically poor since speed varies with changing load. The use of speed control systems also affects the regulation of this type of motor. However, the nature of most applications of series motors are such that poor regulation is anticipated and provided for.

From the foregoing discussion, it can be seen that no one type of motor is suitable for all adjustable speed applications. Each type has definite advantages and limitations.

Table I—Speed Regulation of D-C Motors

Type of Motor	Speed Adjustment	Max. Variation in Speed, %
Shunt wound or stabilized shunt wound, constant speed continuous duty motors.		
(a) 5 hp and less	Full field	12
(b) Larger than 5 hp	Full field	10
General—purpose compound wound motors, all ratings	Full field	25
Shunt wound or stabilized shunt wound, adjustable speed, varying-duty motors.		
(a) 1½ hp and less	All	25
(b) 2 to 5 hp inclusive	All	22
(c) Larger than 5 hp	All	15



ACCESS DOOR for F-89 Scorpion twin-jet interceptor is spotwelded in a three-phase machine. Being part of the fuselage, and therefore a primary structure, door must have rigidity and a smooth outer surface to reduce drag.

Spotwelding Highly Stressed Aluminum and Magnesium Assemblies

A. SCHOELLERMAN AND S. JENKINS
Northrop Aircraft, Incorporated

THERE ARE SEVERAL FACTORS the designer should consider when applying spotwelding to the assembly of highly stressed parts made of aluminum or magnesium. These factors include, among others, making welded areas accessible to electrode heads, checking the ratio of thicknesses for the materials to be joined, matching different alloys for electrical resistance, and allowing proper edge distances.

Although most aluminum alloys can be spotwelded, there is considerable variation in their welding characteristics. Table I gives ratings for the weldability of various alloy combinations. Joints made in high-tensile alloys like 75S-T and 24S-T have consistently high strength and exhibit no separation between sheets. The chromium-bearing alloys, such as 61S, 52S, and 53S, are apt to develop porosity and cavities, particularly when hardened. Alloys 3S and 52S are generally free from cracks and porosity, but are subject to sheet separation; they also have lower weld strength, less consistency, and greater indentation. As for the Alclad materials, such as 75S and 24S, these can be spotwelded in any form.

When dissimilar aluminum alloys are joined, their relative electrical

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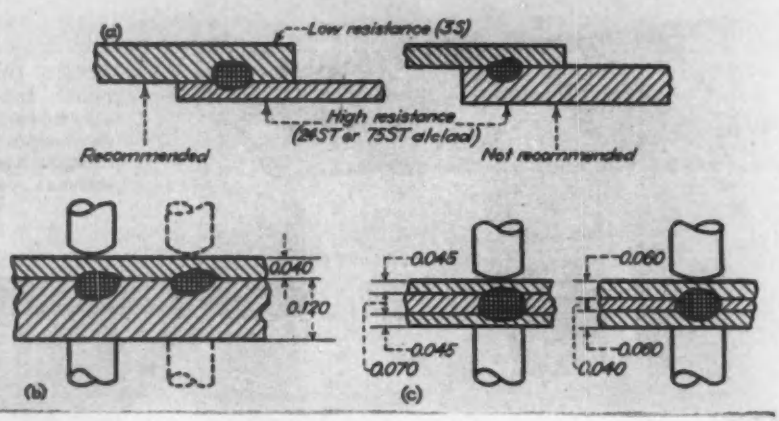


Fig. 1—Electrical resistances of different alloys (a) are balanced by making resistances inversely proportional to thicknesses. This relationship applies to max ratio of 3 to 1 for two thicknesses (b) and for three or more thicknesses (c) arranged symmetrically.

Table I—Weldability of Aluminum Alloy Combinations

Alloy	75STAL	24STAL, 24SRTAL	3SH, 3S-½H	52SH, 52S-½H	75ST, 17ST, 24ST (EXTR)	53SW, 53ST	17SOAL, 24SOAL	2SO, 3SO, 2S-½H 52SO	2SH, 53SO
24STAL, 24SRTAL	A	A	A	B	A	A	C	C	C
75STAL	A	A	A	B	A	A	C	C	C
17SOAL, 24SOAL	C	C	C	B	B	B	A	B	B
17STAL, 17SRTAL	A	A	A	B	A	A	C	C	C
75ST-EXTR	A	A	A	B	A	A	B	C	C
24ST, 24ST-EXTR	A	A	A	B	A	A	B	C	C
3SH, 3S-½H	B	B	B	A	B	B	B	B	B
52SH, 52S-½H	B	B	B	A	B	B	B	B	B
53SW, 53ST	A	A	A	B	A	A	B	B	B

A—Excellent; B—Fair; C—Not Recommended

resistance and melting points should be closely matched. Thus, fully heat-treated or cold-worked alloys—75S-T, 24S-T, 61S-T, 53S-T and 52S-½H—can be spotwelded together comparatively easily, as in the case with soft or fully annealed 3S, 52S-O, 61S-O, 75S-O and 24S-O alloys. However, welding of 24S-O and 75S-O in combination is not recommended. On the other hand, commercially-pure 2S and 3S have higher melting points than do the copper or magnesium bearing alloys, making them more difficult to join.

Design Considerations

Mechanical Properties. A spotweld develops its fullest strength when subjected to shear loads, but the strongest individual spotweld does not necessarily produce the strongest joint. Rather it is a combination of spotwelds in a definite pattern or design that gives the desired results.

When two or more different alloys in combinations of equal thickness are spotwelded, the design value is usually based on the lower strength alloy or the thinner sheet. If two parts are stressed so that the joints are in tension and individual spotwelds in shear, the objective is to secure a joint having an ultimate strength equal to that of the parent material. In cases where maximum strength is needed in a lap joint, two or more rows of spotwelds are required.

The tensile strength of spotwelds is approximately 25 percent of the shear strength, so that this joining technique should not be used on an assembly where any appreciable tension load will be applied to the spotwelds.

Thickness Ratios. Gage combinations, as well as materials, play an important part in the weldability of joints. When joining sections made of the same alloy, more heat is required to fuse a thick section to a thin section than is needed to weld sections of equal thickness. Thus, if differing gages must be joined, it is more economical to use a high resistance alloy that is of thin gage with a low resistance alloy that is of thicker gage. Design values for unequal sections are based on figures for thinnest gages. A lap joint between thick-gage 3S, which has low electrical resistance, and thin-gage 24S-T or 75S-T Alclad, which has high resistance is shown in Fig 1 (*A*). For two unequal thicknesses of material, the maximum allowable ratio is 3 to 1, Fig. 1 (*B*); and for three or more symmetrically arranged thicknesses, the maximum allowable ratio is 3 to 1, Fig. 1 (*C*). Existing equipment limits total thickness of section(s) to about 0.375 in., but this figure necessarily must be keyed to the equipment available for a given job.

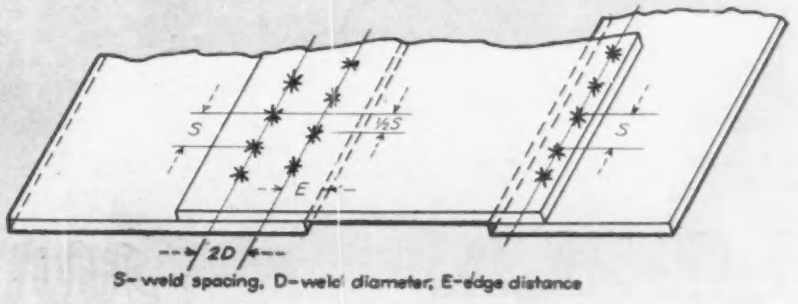
Edge distance. The distance from the center of a weld to edge of sheet is more important in spotwelding than in riveting. Insufficient edge distance

Table II—Spot Weld Spacing and Dimensions for Aluminum and Magnesium Assemblies

Sheet Thickness, in.	Min. Edge Distance, in.	Minimum Spacing, in.		Electrode Clearance, in.	Approx. Weld Diameter, in.
		Al Alloy	Mg Alloy		
0.016	0.19	—	—	0.25	0.09
0.020	0.19	0.38	0.25	0.28	0.12
0.025	0.22	0.38	0.28	0.28	0.15
0.030	0.25	0.38	0.30	0.35	0.18
0.035	0.25	0.38	0.32	0.35	0.21
0.040	0.28	0.44	0.35	0.35	0.24
0.045	0.31	0.47	0.38	0.35	0.27
0.050	0.31	0.50	0.41	0.35	0.31
0.060	0.34	0.53	0.47	0.35	0.33
0.070	0.38	0.60	0.53	0.35	0.35
0.080	0.41	0.69	0.61	0.35	0.37
0.090	0.44	—	0.67	0.50	0.38
0.100	0.44	—	0.75	0.50	0.39
0.120	0.50	—	0.91	0.50	0.39
0.125	0.56	—	0.94	0.50	0.39
0.157	0.62	—	1.12	0.50	0.39

General design procedure for spotwelding stainless steel is the same as that for aluminum alloys. Maximum thickness ratio for members joined on primary assemblies is 3 to 1; less edge distance and no tack or "stop" rivets are required.

Fig. 2—Spacing of welds, both as individual spots and as rows of spots, is critical if full spot strength is required. Table II lists dimensions for proper spacing.



permits pressure and heat to cause spitting and extruding of molten metal from between the sheets, resulting in a weak weld and reduced operating speeds. Excessive edge distance allows gaps to form between facing surfaces. When two different gages are joined, the diameter of the spots and edge distance are determined by the thicker sheet.

Spot Spacing. Requirements for spot spacing are given in Table II and pictorially indicated in Fig. 2. Values for minimum spacing are the smallest that will allow full spot strength. Closer spacing causes "shunting" action during welding.

Design Limits for Aluminum Alloys

Spotwelded aluminum alloys are used in the fabrication of primary aircraft structures except when joining such parts as: Flanges to shear webs; spar caps or shear web flanges to wing covering; ribs to spars or shear webs; brackets, hinges, fittings and related items; and at truss panel points in spars or ribs. "Stop" rivets are used at juncture points of stringers or stiffeners with ribs at the ends of stringers.

Generally, fittings are not constructed of laminated spotwelded elements. No less than two spotwelds are required when attaching clips and similar devices, because one weld might induce torsional failure. If only a comparatively few spotwelds are used on a design, it is more economical and efficient to use rivets.

Roll Spotwelding of Aluminum Alloys

When the reciprocating elements of standard spotwelding equipment are replaced by a roll carrying a series of radial electrodes, as many as 300 spots per minute can be made in 0.32-in. material. This method results in a 500 percent increase in welding speed.

The number of spots that can be made without electrode dressing is greatly increased, because a fresh electrode surface is presented for each spot. Electrodes can be cleaned as they revolve and the instantaneous temperature of the material surface thereby reduced. In addition, the rolling action of the electrodes prevents separation of the sheets between successive welds. The combination roll-seam spot welder, Fig. 3, is used in the aircraft industry.

Spotwelding Magnesium Alloys

Magnesium alloys can be successfully spot- or roll-welded in sheet and extruded form on equipment normally used for welding aluminum. If comparable production speeds are to be attained, the magnesium weld surfaces must be thoroughly cleaned. Less current is needed to fuse magnesium than aluminum, so that thicker magnesium sections can be welded (within the limits of available equipment).

The edge distance values shown in

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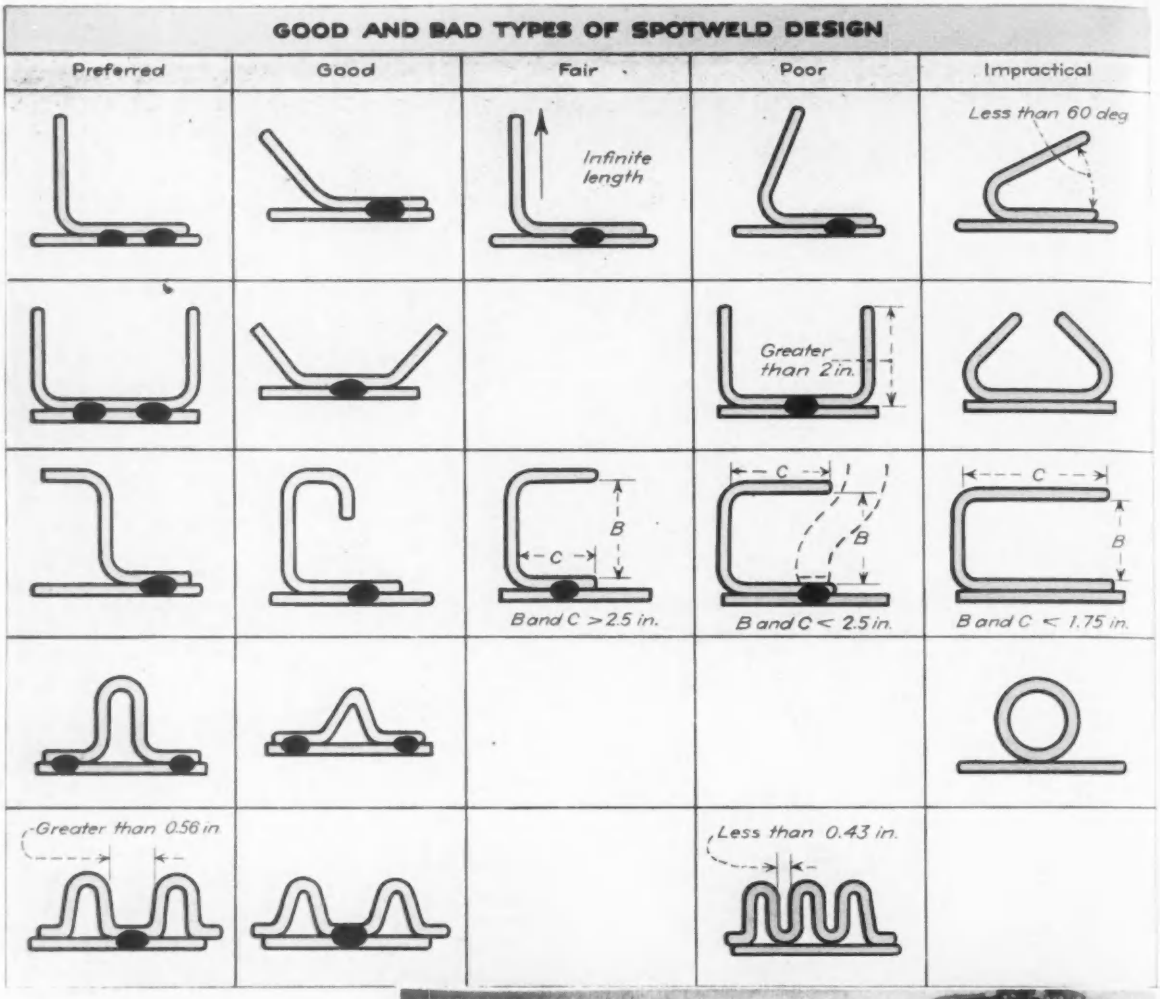


Fig. 3—Roll seam spot welder used for airframe structures is capable of joining two 0.125-in. sheets of 24ST or 75ST aluminum alloy.

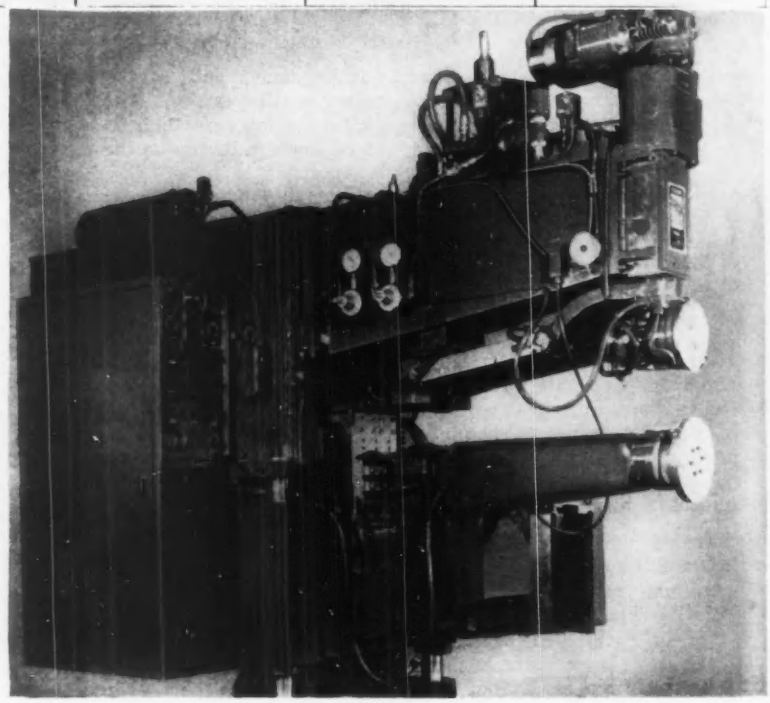


Table II are based on the required amount of space necessary to obtain a consistently good weld in QQ-M-44 (FS-1H) magnesium alloy. After welding, it is possible to trim to the edge of a weld without inducing subsequent failure.

Satisfactory non-structural welds can be made in magnesium when a maximum allowable thickness ratio of $2\frac{1}{2}$ to 1 is used. More than two pieces can be welded under the following conditions: When two thin pieces are followed by a thick piece, when a thin piece is welded on each side of a thick piece (thickness ratio of thick-to-thin piece not to exceed 2 to 1), and when thicknesses do not vary more than 25 percent in relation to each other.

TECHNICAL NEWS

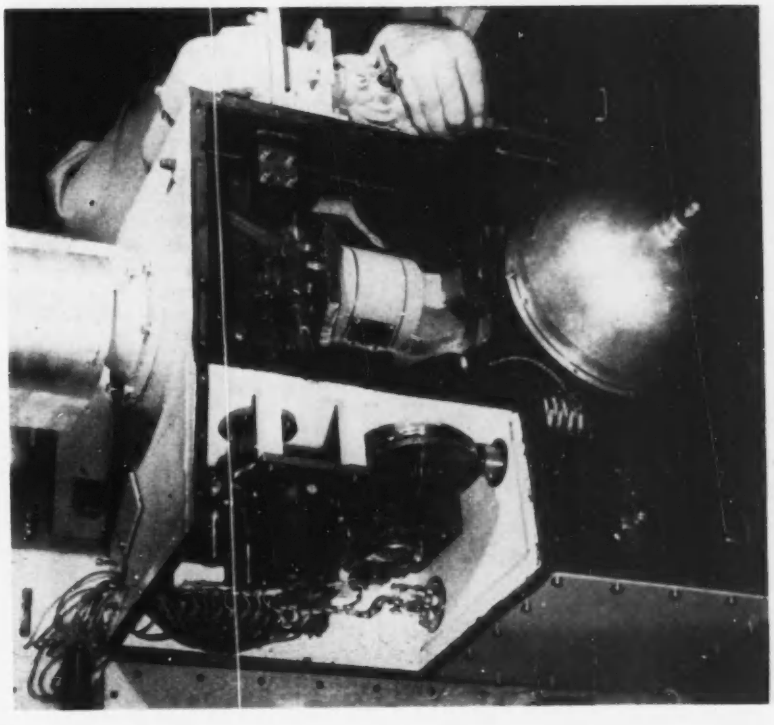
New Magnetic Robot Helmsman to Steer Navy Flattops

TUBELESS VERSION OF the Sperry electronic automatic pilot has been accepted by the U. S. Navy as the first automatic steering system for aircraft carriers. A static magnetic field capable of withstanding heavy naval service was developed to replace electronic vacuum tubes used to control earlier automatic pilots. A "magnetic brain" anticipates steering motions and can hold the ship precisely to straight gyro courses despite wind and sea forces.

Without human aid the robot will steer prescribed zig zags and follow course schedules computed by special navigation devices. Big use on the carriers will be steering the ship into the wind during launching and landing of aircraft, an operation which requires keeping the wind a precise number of degrees off the port bow to neutralize the turbulent stream of air which flows around the ship's island.

Turning to a new course can be accomplished in the least possible time without overshooting the course. The robot anticipates the ship's steering motions by measuring the rate of turn and comparing this rate to the ship's departure from the desired course. An integrator compensates for wind effects and errors in settling onto the new course. Deck personnel can take over and steer the ship manually at any instant by turning the manual steering wheel.

Developed by the Sperry Gyroscope Company, the first unit will be installed on the U.S.S. Oriskany.



ABOVE. Control panel dials show quartermaster the ship's course, rudder commands, and positions calculated by the robot's magnetic "brain" as it automatically directs the vessel to a new course. The brain is located beneath the panel. Small ship's wheel is for manual steering. Device being held by Sperry engineer is portable controller that permits steering ship from remote points such as the open bridge.

BELOW. Hydraulic power unit. Oil pumped through high pressure lines operates hydraulic motor to control ship's rudder movements in response to commands of the magnetic brain. The motor and other components are mounted in the oil to save space.

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Armed Forces Personnel Requirements May Cause Employment Problem

WASHINGTON—Armed Forces requirements reaching over 400,000 men for 1952 may cause personnel problems in Engineering departments. Both reservists and draft elegibles will be involved.

An upward swing will come for the draft calls as spring comes along. And with the increased draft will also come more calls for inactive reserve officers, since:

1) The President has already approved a year-end strength for the armed forces of somewhere between 3,700,000 and 3,800,000 men.

2) A law passed by Congress last year makes it mandatory for the armed forces to release inactive reservists after 17 months of post-Korea duty. Release has already started, and the peak will be around March.

3) Length of service for organized reserves is fixed at about 24 months. That means a mid-summer release of organized reservists.

4) The Air Force is rapidly expanding from the present 90 wings to about 124 this year—143 next year.

The Pentagon is figuring that it will require at least 300,000 more men in uniform this year. Being married won't help get a deferment. Men who married after the Korean outbreak are being drafted in some areas right now.

Deferments are a liability too. Once a draft eligible man is deferred, he automatically becomes liable for draft at any time up until his thirty-fifth birthday. If, by accident, he is neither deferred nor drafted, his liability ceases after age 26.

Student deferments are not binding on the draft boards either. The IQ tests now being given to college students are guides only for the local boards. They still have the power to draft even the man making the highest mark.

Requirements for reserve officers for all of the services still remain basically the same. The services generally want only the younger and lower ranking officers. There are, however, notable exceptions. These generally apply to officers who are electronics specialists, aeronautical engineers, steam power plant specialists, etc.

The Air Force is planning a large call of inactive reserve officers who were combat-crew navigators and bombardiers. They will be sent to combat crew training for new bombing wings now being formed. In addition, some pilots will also be called. At present, about 79 per cent of all officers on active duty in the Air Force are reserve officers.

The Army will call about 10,000 reserve officers involuntarily, mostly captains and below. No enlisted reservists will be called involuntarily as individuals, but some units may get orders. Three National Guard Divisions will also be called to active duty in 1952.

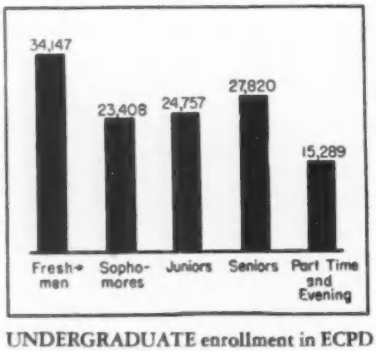
The Navy's calls will remain slight. Total among reserve officers this year will be several hundred lieutenants and below who have had little active service. Some reserve units will be called, particularly in aviation. The Navy will also follow the Marines' lead of calling "a number" of reserve pilots involuntarily. Total Marine Corps in this category will number about 1,000 officers—captains and below. Pending expansion approval, only a slight number of Marine Corps ground officers are expected to be called involuntraily.

Engineer Supply Will Be Even Shorter in '52

Only 28,000 engineering students will graduate in 1952 to meet the current demand of from 60,000 to 90,000 engineers. Figures issued by the U. S. Office of Education and American Society for Engineering Education indicate that 1952's crop will fall short of the '51 yield by 10,000 graduates.

Graduates who are members of ROTC units or eligible for military draft will further deplete the supply, so that industry will be 40,000 to 70,000 short of estimated requirements at the end of 1952.

While freshman engineering enrollment figures are up 16.2 per cent over 1950, industry will not feel this increase for four years. Portions of this increased enrollment will be lost, since a larger number of freshmen are joining ROTC units.



UNDERGRADUATE enrollment in ECPD accredited institutions for 1951.

Graduate enrollments are almost three times what they were in 1940. This fall, 13.1 per cent of all engineering students are taking graduate work.

The May issue of PRODUCT ENGINEERING will carry a special section on engineering department organization and procedures. Included will be feature articles covering recruiting and training graduates.

Lockheed Moves to Ease Engineer Shortage

A PILOT GROUP of 50 men and women is being assembled by Lockheed Aircraft as engineering draftsmen to release experienced arronautical engineers for advanced assignments. Requiring no engineering degree, new-hired employees in this group will heavy-up much-used blueprints, redraw finished prints, prepare bills of materials, and incorporate design changes on duplicate prints.

Educational background of the new draftsmen vary from high school drafting and blueprint courses to some college engineering training. Immediately after hiring, each employee receives an instruction course in Lockheed drafting techniques. Qualified personnel then become eligible for an additional four weeks of junior engineer-draftsmen instruction.

This plan has been coupled with a long-range training program for engineers that includes counseling on courses for individual professional advancement, job rotation, on-the-job training assignments, and joint payment for extra educational courses.

Materials Engineering Course at Michigan

THE UNIVERSITY OF MICHIGAN has announced the establishment of a course in the College of Engineering leading to the degree of Bachelor of Science in Materials Engineering.

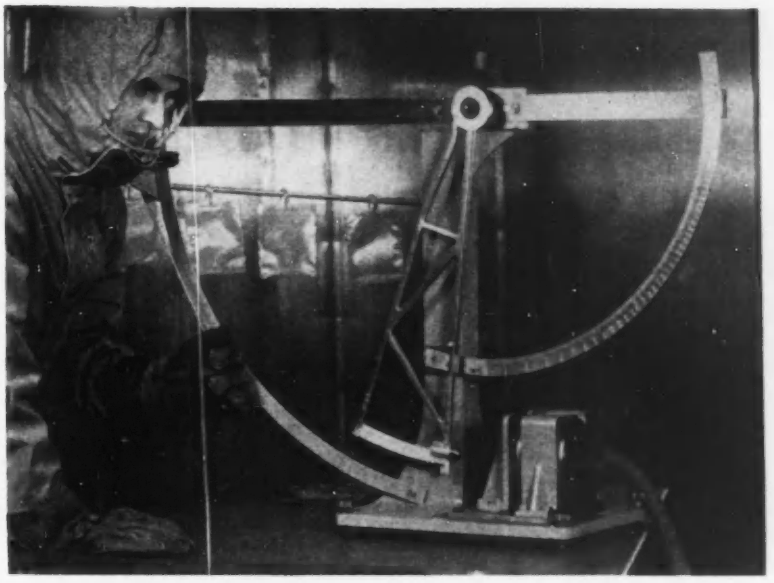
Similar to Metallurgical Engineering in some respects, the course requires more advanced work in mathematics, stress analysis, machine shop, machine design, specifications, corrosion properties of materials, and fabrication operations. Materials studied include cements, wood, metals, rubber, and plastics.

Emphasis will also be placed on finishes and coatings such as paints, varnishes, lacquers, and enamels. Initial enrollment was in February 1952.

Water in Frit Causes Ceramic Coating Defects

NATIONAL BUREAU OF STANDARDS investigations have revealed that water present in the frit is responsible for hydrogen produced defects found in porcelain-enameled and ceramic-coated steels. Scientists traced the origin of the gas that causes blistering and "reboil" by substituting heavy hydrogen, at one point at a time, in water vapor in the furnace, water used for milling and suspending the enamel slip, water chemically combined in the clay for suspending the slip, and water in the frit used in the enamel. Heavy hydrogen constituted about 53 more percent of the total hydrogen recovered from the specimen with the "heavied" frit as compared with about one percent from the next most important source of gas, the quenching water.

Elimination of troublesome defects depends on the development of a method for preparing water-free frit. Two methods have been evolved by NBS: drying normally prepared frit by vacuum melting, and preparing frit from dried materials. The vacuum-melted frit produced the best results with no reboiling, lifting, or fishscaling. The second method proved less successful; some defects developed, though not as many as with normally prepared frit.



ARCTIC CONDITIONS are simulated in this 50-below-zero cold room of the Olin Industries new Research and Development Laboratory while a heavily clothed technician uses a pendulum impact machine. Believed to be the first laboratory designed especially for the study of cellophane, polyethlyne, and other film packaging materials, it will permit wide research in packaging by using apparatus ranging from the cold room to an infra-red spectrophotometer.

Mineral Ore-Like Catalysts Improve Engine Performance

SYNTHETICALLY COMPOUNDED CATALYSTS cast in the cylinder head or piston of an internal combustion engine produce more complete combustion and reduce carbon formation and detonation tendency according to data developed by Dr. Berkman of the Associated Development and Research Corporation.

Natural ores and minerals chosen for their catalytic activity are compounded into a water-and oil-proof synthetic ore. Numbering between 16 and 25, each mineral performs one of these functions: catalyst in hydrocarbon decomposition, anti-knock agent, catalyst in dehydrogenation, catalyst in oxidation reaction, and catalyst in carbonium reaction.

Purpose of the synthetic ore is to effect reversibility in reactions and to establish essential mobile criteria. During combustion, oxidation minerals accelerate combustion and make it more complete, while anti-oxygens prevent spontaneous combustion and detonation. The formation of carbonium ions also acts as a deterrent for knocking. Specific hardening, plasticizing, and wetting agents of the mineral type are added to enforce greater strength and photoluminescent minerals contribute activation through the emission of electrons.

Major advantage of catalytic combustion is the increased octane rating of gasolines it makes possible. Numbers have been increased as much as twenty-five in tests of the development. Researcher Berkman predicts that her discovery will permit 10:1 compression ratios in auto engines.

One Coat Porcelain Enamel Finish Developed

NEW PROCESS for finishing kitchen appliances and other porcelain-enameled products has been developed jointly by Ferro Corporation and Republic Steel Corporation. Single coat of titania-opacified enamel is applied directly to enameling iron and many cold-rolled steels eliminating ground coat and necessity of using premium steels.

Advantage of one coat finish include increased resistance to heat, impact, thermal shock and torsion; and easier machining producing clean edges after drilling, shearing and sawing.

Prime phases in the new process are a special pickling process and non-galvanic-nickel deposition. After the steel has been cleaned and rinsed in the usual manner, it is submitted to a special pickling process that permits the removal of more iron than conventional sulfuric acid and leaves a rough surface on the metal. Nickel is deposited on the steel by chemical reduction so that no iron goes into solution, and the rough surface required for good adherence is maintained.

Rinsing of the steel in cold water is the final step in preparing the metal. The one coat finish is applied only half as thick as ordinary porcelain enamel coatings.

Radar Makes Deadeye Pilots

SMALL AUTOMATIC RADAR to direct the guns of jet fighters is being produced on an assembly-line basis by General Electric. By feeding information into a computing gunsight the device eliminates guesswork by the pilot and guarantees a direct hit if the flyer keeps the target on the crosshairs of the sight. The new radar eliminates pilot's loss of timing due to the high speed of modern jet planes.

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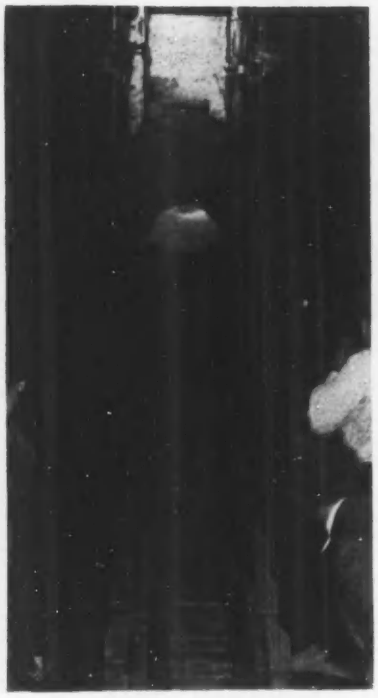
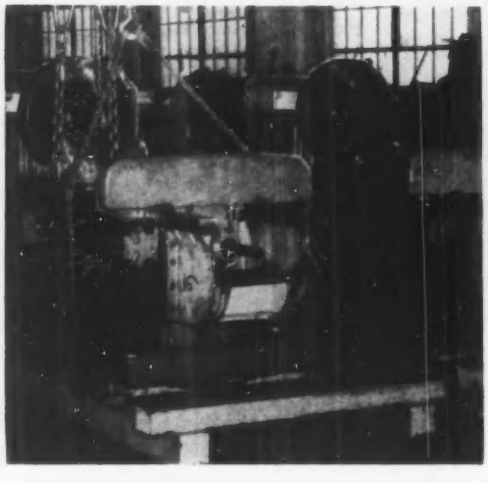
THE NEWS IN PICTURES

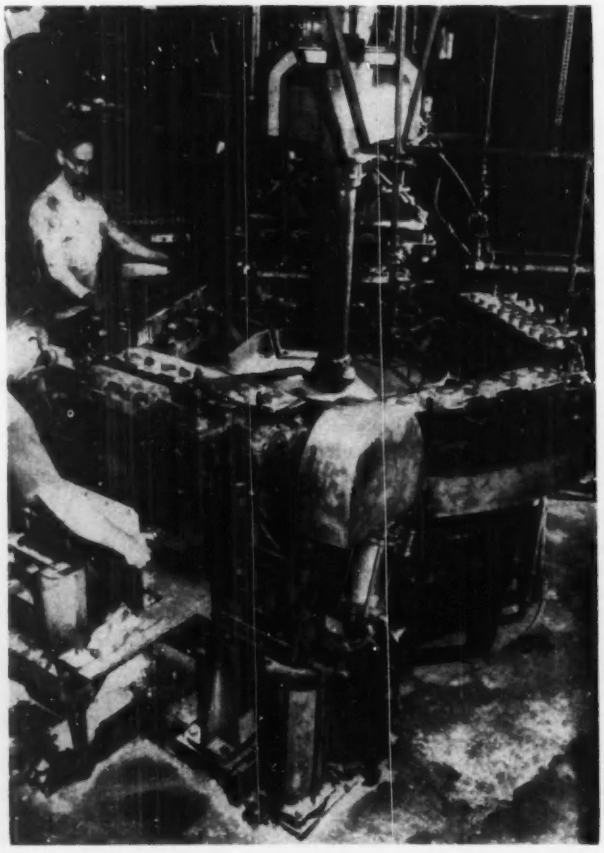


FASTEST AND MOST POWERFUL PLANE in transcontinental service is the claim Douglas Aircraft makes for the new DC-7. Powered by four Wright compound engines capable of developing 13,000 hp, the plane will slash one hour flying time off the New York to Los Angeles schedule, with a cruising speed greater than 360 mph. Energy of exhaust gases is utilized to operate three auxiliary turbines that are geared back to the engine crankshaft to provide greater horsepower without additional fuel. The DC-7 will carry 60 passengers in deluxe style, or 95 coach passengers.

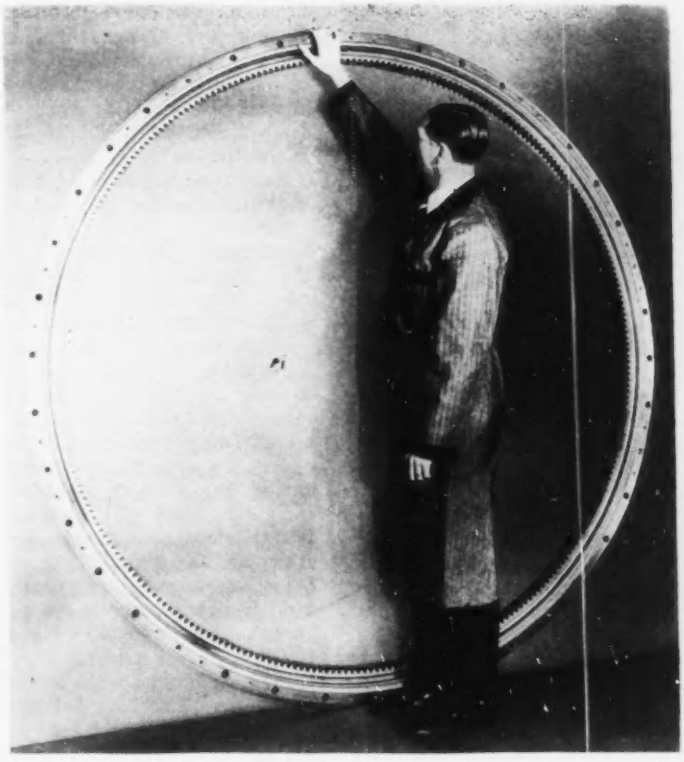
FIRST SEAMLESS STEEL TUBING produced in the United States by the "Ugine-Sejournet" hot extrusion process is viewed anxiously by employees of Babcock and Wilcox's Tubular Products Division. The French process makes possible for the first time the extrusion of hollow and solid sections of metals that are difficult to forge, as well as permitting finer and more complicated structures to be extruded from easier-to-forge metals.

FIRST MACHINE TOOLS built by Subcontracting Cameron Can Machinery Company for the Gisholt Machine Company are delivered as subcontracting is started to help break the machine tool bottleneck in defense production. Subcontractor builds basic machines which are then tooled and tested at Gisholt. Special priorities have also been granted to help speed machine tool manufacture.

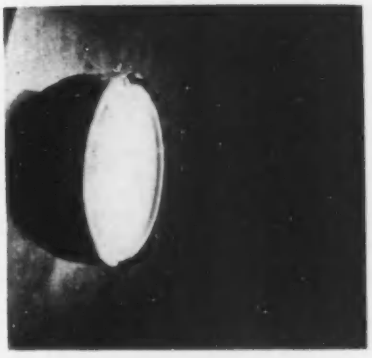


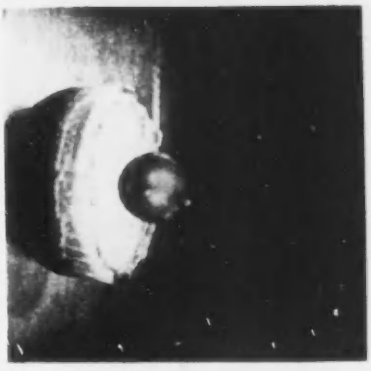


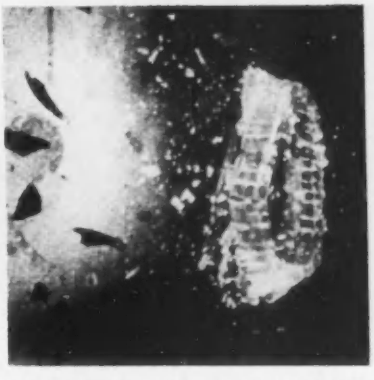
AUTOMATIC CORE MAKER for automotive castings boosts production 600 percent. Made by Osborn Manufacturing Company, the machine blows the core, brings empty core boxes to the blower and removes filled boxes, and extracts the cores from the filled boxes onto dryer plates. Requires only two operators who can be trained in minutes. Machine produces 180 cores per hour.



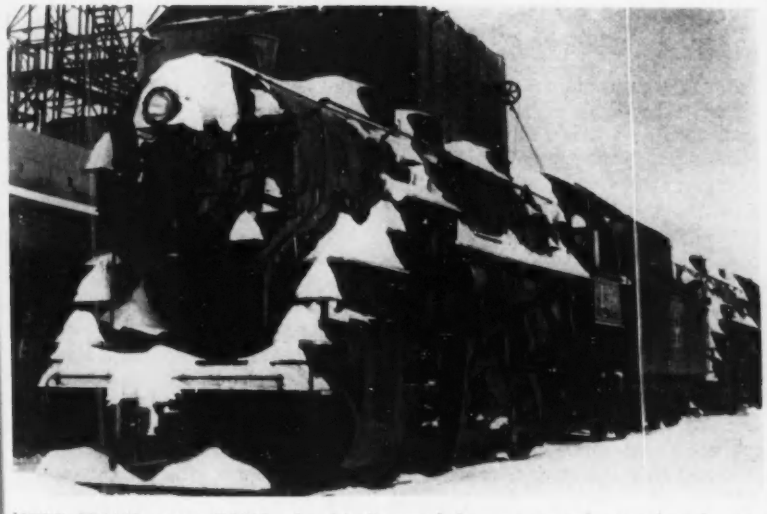
WORLD WAR II SURPLUS Colonial Broaching Machine was remodeled to cut the 294 teeth in this 6-foot tank turret ring at the Detroit Tank Arsenal. 27 cutting strokes of the machine produce gear teeth so accurate that no subsequent finishing is required while reducing machining time from 4½ hours to 30 minutes. Teeth are broached 11 at a time, and a fixture designed by Colonial engineers automatically and accurately indexes the ring for cutting the next group of teeth. New method eliminated ¾ of the machine tools previously required as well as effecting a saving of $400 per day.







SHATTERING OF A TELEVISION TUBE by a swinging steel ball is caught by an Eastman Kodak high speed camera. Pictures were taken at a speed of 3,000 frames per second slowing down action for intensive study and analysis.



MORE THAN 1,000 TONS of critically needed scrap turned up when hunters uncovered 8 switching locomotives idled by diesel replacement in the yards of the Belt Railway Company. Shutdowns of open hearth furnaces have emphasized the critical scrap situation. Biggest problem is encouraging the return of dormant scrap—found wherever obsolescence, wear, accidents, or damage has forced retirement of metal products. All kinds of metallic scrap are still urgently needed.

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Progress Reported in Developing Turbo-Prop Airplane Power Plant

CONTINUED RESEARCH and development will provide a turbo-prop airplane far exceeding the capabilities of reciprocating engine planes, and for some specific tasks, turbo-jet powered planes. This prediction was made by William W. Fox of Consolidated Vultee before the 20th Annual Meeting of the Institute of the Aeronautical Sciences as he presented a progress report on the work already done on this type power plane. However there are complicated design problems that must be solved before large scale production is possible.

Since the first turbo-prop powered plane was flown in 1945, five such aircraft have been built and have supplied experimental and operational data while accumulating 150 hrs of flying time. Single engine, twin engine, and four-engine aircraft have revealed similar problems that must be solved. Most significant lesson learned was that engine failure in this type plane can lead to a more disastrous situation than with other types.

In a single engine installations, severe drag conditions and loss of longitudinal control can be encountered from which there is insufficient time for recovery when the turbine failure occurs within a few hundred feet of the take-off or landing surface. Multi-engine installations have the problem of directional and lateral control requirements during an engine failure that far exceed those required for reciprocating engine installations.

The principal defect in engine control systems to date has been the mechanical failure of electrical components. Manufacturing and mechanical techniques will have to be developed to provide the type of reliability required, and servicing and trouble shooting procedures provided so that typical aircraft mechanics and electricians can accomplish the task.

Extension shafting problems have been complex and present shafting is not performing as well as desired. Convair believes the solution of this problem will materially advance turbo-prop power plants since buried engine installations offer very large performance gains.

One problem that is unique for the turbo-prop plane is the control of the magnitude of approach condition thrust. Normal operation at idle throttle on the low pitch propellor stop, used in reciprocating engine installations, is entirely unsatisfactory for the turbo-prop equipped aircraft. Reason for this is the very low propellor blade angle required to accommodate the required high idle speed of the turbine. Since the thrust versus airspeed curve for constant blade angle operation is extremely steep, very large changes in thrust occur during a standard landing approach resulting in a severe ballooning or floating tendency in the airplane.

Fuel flow is the cause of thrust variations due to compressor bleed and other accessory load variations that affect engine power output for a given airplane speed. Accommodating both AN-F-48 and AN-F-58 fuels remains a problem that must be solved.

Assymetrical thrust variations during landing or stall approaches at idle throttle have been one of the most annoying problems in the development of multi-engined turbo-prop craft. Symmetrical thrust requires all engines to operate at equal values of rpm, fuel flow, and propellor low pitch blade angle. Assymetrical variations are the result of the accumulation of manufacturing tolerances. Most feasible solution to this problem appears to be tight tolerances in the fuel flow control system.

Even the limited flight tests of this type power plane have indicated that the operation of a turbo-prop airplane is in reality quite simple when all the components function properly. Chief advantages are simple engine run and checkout procedures for pilots and the short time required for takeoff.

Small Design Defects Cause Many Air Force Accidents

MANY OF THE MECHANICAL-DEFECT ACCIDENTS suffered by the Army Air Force are due to deficiencies or oversights in design. Investigation and tabulation of data of every Air Force accident since 1908 prompted this conclusion. Sidney Berman, Directorate of Flight Safety Research at Norton Air Force Base told the I.A.S. that designers and aeronautical engineers were expending their brains and energy to obtain an aircraft whose structure is airworthy and which is aerodynamically supreme. But at the same time, they have neglected details of systems, equipment and their installation.

In reviewing Air Force accidents five design oversights were found to be responsible for a majority of the mechanical-defect losses.

1. Lack of design planning in installing an inferior type of limit switch to control a vital precision part.

2. Lack of safety thinking in failure to provide a safe space for a checklist.

3. Lack of understanding of the primary concepts in not providing protection from jamming of vital controls units of the aircraft, as well as locating vital equipment in line with the plane of rotation of the propellors.

4. Lack of proper functional design in manufacturing a propellor reversing mechanism which could easily malfunction.

5. Lack of sufficient foresight in not designing a fuel tank cap and cover which would be operationally fool-proof.

Berman recommended that aircraft manufacturers establish a department of safety engineering to work in close contact with the design engineering department. Such an organization would produce aircraft with built-in safety and eliminate the necessity of design changes after an accident has occurred. He urged designers to become safety conscious in their work.

Platinum Electrode Replaces Diaphragm in Loudspeaker

BIG IMPROVEMENTS IN the quality of sound reproduction are predicted by the Institute of Inventive Research as a result of a device invented by Frenchman Siegfried Klein.

Called the "Ionophone", the invention eliminates the mechanical diaphragm normally used in loudspeakers, and replaces it with a platinum electrode. When heated to a high temperature, the electrode produces an ionic cloud that responds almost instantly to changes in the strength of a high frequency electric field. The cloud expands and contracts to produce sound waves and the quick response enables it to practically eliminate distortion.

All sound including ultrasonic ranges can be reproduced with good fidelity and efficiency since electrical energy is translated directly into sound without a mechanical membrance.

Mica Flakes Made Into Sheet For Electrical Insulation

GENERAL ELECTRIC COMPANY has announced a process by which minute mica flakes are so treated that a force is generated to hold the tiny particles together producing an electric insulation in a continuous sheet in thicknesses ranging from two-thousands to six thousands of an inch.

Greater uniformity of thickness and the absence of voids are responsible for an insulation that has good dielectric strength. Capable of being impregnated with resins and bonded to paper, glass, and cloth for greater strength and improved electrical properties, the G. E. "Micamat" can be used in heating devices, molded into shapes for motors and generators, or machine-wrapped on bars and cables.

G. E. predicts that the new material may free the United States from foreign dependence on mica supplies since Micamat can be made from the mica found in American mines; mica that is usually inferior for insulating purposes. Production is planned for 1952.

Dry Coloring— A Revolution in Plastics

PLASTIC PRODUCTS PRODUCED in unlimited varities of transparent, translucent, and opaque colors are the result of dry coloring, a process developed by the plastic industry to meet the demand for new tints and hues. Simple and efficient in operation, the process permits the molder to produce his own injection molding powder by mixing a dry colorant with virgin crystal styrene plastic at the time of molding.

Eliminating precolored compounds, the new technique has reduced molders' inventories as much as 75 per cent, enabled tighter scheduling and control, and permitted easier, quicker color changeovers.

The scope of plastics applications has been broadened by the variety of color effects made possible. Mottled tones are produced by dry blending the major component, and then adding the minor colors in pellet or granular form. Reduced breakdown of the colorants during compounding and processing improves the appearance of fluorescents and dry phosphorescents.

Dry coloring, now commercially tested and proved, is being used in the manufacture of wall tile, radio cabinets, refrigerator components, and lighting fixtures.

LAYING DOWN ASSAULT FIRE with the Army's new lightweight rifle.

Lightweight Army Rifle Increases Firepower

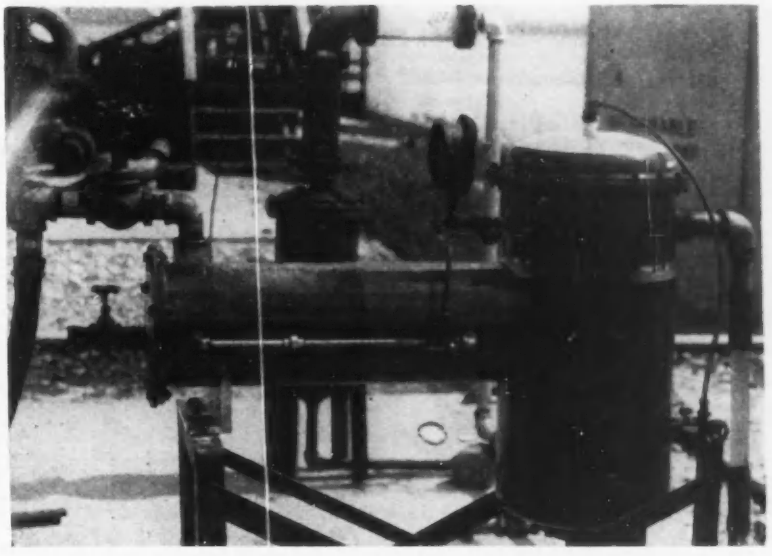
NEW RIFLES incorporating semi-and full-automatic features have been developed by the U.S. Army to fire the new T-65 .30 calibre shell, which is shorter and lighter than present M-1 ammunition though maintaining the same stopping or wounding power.

Design details of the new rifle are a secret, however, the Army has revealed that the weapon is gas operated and weighs about eight pounds, 1¾ pounds lighter than the M-1 (Garand).

Rate of full automatic fire is 700 rounds per minute, and for brief periods the rifle can deliver assault fire at machine gun rates. In tests, 100 rounds were fired in one minute with necessary changes of ammunition. A clip holds 20 rounds.

In the hands of a skilled infantryman, the new rifle can deliver 48 hits per minute on a man sized target at 100 yards as compared to 34 hits per minute delivered by the Garand.

While the new weapon has wounding power equal or superior to any standard military rifle in existence today, there are no plans for immediate production. M-1's have been ordered because industry has the knowhow to mass produce these in large quantities and quickly.



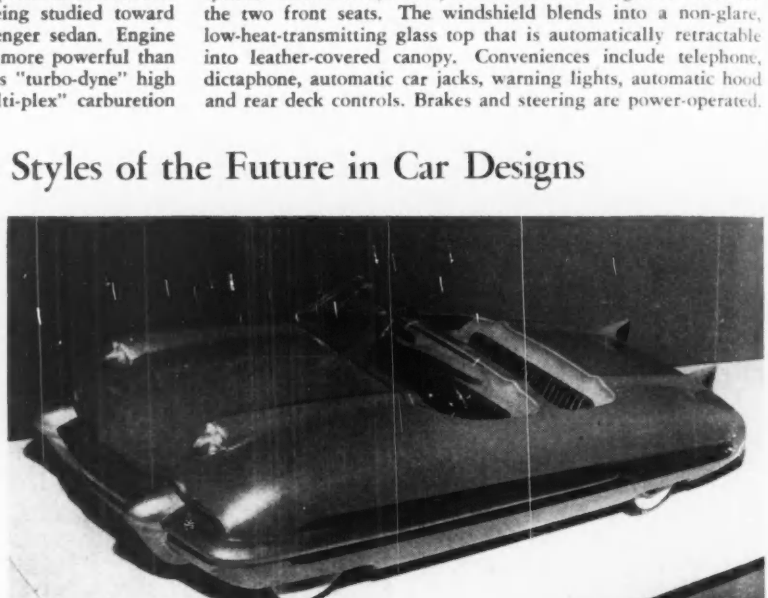
PLASTIC WORKING MODEL of combination gasoline-water separator and filter made at the Fort Belvoir model shop helps army engineers iron out kinks before actual units are placed in production. Researchers study visually the operating characteristics and make design calculations and improvements directly from the model.

UNIVERSITY OF MICHIGAN LIBRARIES

COMING OR GOING, the Continental represents streamlined comfort. A full scale pilot model, it is being studied toward future development as a practical five passenger sedan. Engine performance is secret, but Ford admits it is more powerful than anything they are now building, and utilizes "turbo-dyne" high compression combustion chamber and "multi-plex" carburetion system. Instruments, levers, and switches are organized between the two front seats. The windshield blends into a non-glare, low-heat-transmitting glass top that is automatically retractable into leather-covered canopy. Conveniences include telephone, dictaphone, automatic car jacks, warning lights, automatic hood and rear deck controls. Brakes and steering are power-operated.

Ford Reveals Styles of the Future in Car Designs

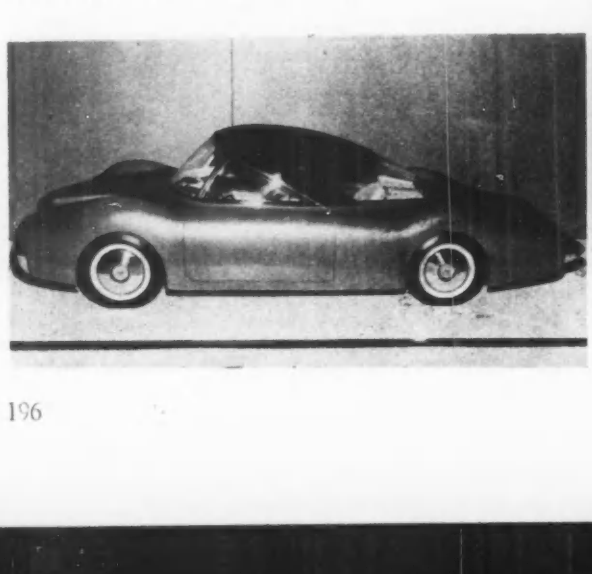
FORD MOTOR COMPANY ENGINEERS and designers went to work on automobile designs for the last half of the twentieth century and came up with the 3/8 scale models pictured on this page. Trending toward a super streamlining with a minimum of outside accessories, the models are the last work in luxurious driving and include comfort devices such as individual head rests, telephones, dictaphones, teletype machines, radar, easy to read instrument panels, and automatic car jacks. One design has a pivoted steering wheel so that the car may be driven from either side.

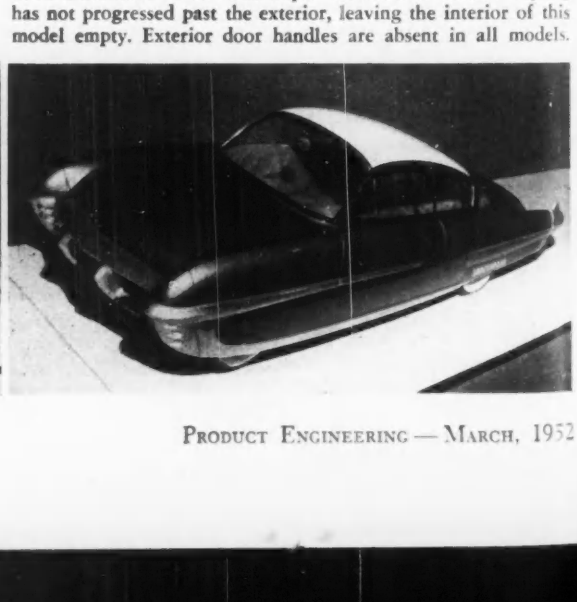


THE MAROC. Built to see just how low to the ground cars can be styled. Speedometer is on the windshield with fluorescent lights indicating speeds. Seats are equipped with individual headrests. Telephone and teletype machine are also included. Steering wheel is so pivoted that changing drivers means merely moving the steering wheel from left to right.

THE MARLIN. Six passenger zephyr complete with radar scope and super streamlining. Speedometer is located in the steering wheel for easier reading.

THE BOLERO. Two door super streamlined sedan. Styling has not progressed past the exterior, leaving the interior of this model empty. Exterior door handles are absent in all models.





How Carbon Deposits Affect Automobile Engine Firing

A PHOTOGRAPHIC ANSWER to this question was presented to the Society of Automotive Engineers by Dr. Lloyd L. Withrow and Dr. Frederick W. Bowditch of General Motors Research Laboratories during the annual SAE convention.

Using a high speed camera, they produced a photo record of the entire engine flame cycle in combustion chambers deliberately crusted and flaked with carbon in a V-8 and two single-cylinder laboratory test engines. Outfitted with transparent quartz heads through which photos could be taken, the engines were run at low speeds under light load conditions, similar to city stop-and-go driving.

In normal automotive engine combustion, the air-fuel charge from the carburetor is ignited by the spark plug and the flame fans evenly across the chamber until the charge is completely and smoothly burned—like the sweep of a grass fire from one side of a field to the other in a high wind. In a combustion chamber coated with carbon, the flame's symmetry is distorted or conspicuously absent. As a result, ignition timing is neutralized; the spark no longer controls firing of the air-fuel charge.

"Mechanical octane" numbers designed into the combustion chamber begin to depreciate. In effect, the air-fuel charge ignites before it is supposed to, and this subtracts from the engine's efficiency and fuel economy with the result that the engine operates roughly and detonation occurs.

Photos of carbon-coated combustion chambers show that before the normal spark from the spark plug can inflame the air-fuel charge, the charge sometimes ignites in a galaxy of tiny explosions, either from hot carbon particles shaken loose in the turbulent gases or from hot carbon flakes sticking to the chamber walls. Although these explosions and erratic high pressures rob an engine of efficiency, they are part of a process by which engines purge themselves of carbon. Carbon particles cause trouble in transit, but they are on their way toward an exit, the exhaust manifold.

Particularly significant was photographic evidence indicating that decomposed products of leaded (Ethyl) fuels were not the only cause of auto-ignition (engine combustion by other means than the normal spark from a sparkplug).

A few years back, many car owners made a practice of purchasing a tank of Ethyl gasoline at intermittent intervals to burn the carbon out of the engine. The present data together with the known chemical facts about the behavior of mixtures of carbon and lead compounds indicate that the lead salts left in the engine by the Ethyl gasoline are indeed capable of purging substantial amounts of carbon from the engine under some operating conditions.

Deposits formed by non-leaded fuels will purge themselves, because of traces of chemical substances in the air. Entering through the engine air intake, these substances not only lower burning temperature of carbon but also speed chemical reactions between carbon deposits and oxygen in the air.

Another important phase of this investigation tracked down so-called "wild ping". This type of knock occurs in some carbon-coated engines when a motorist accelerates suddenly in traffic. "Wild ping" is spontaneous—not the usual xylophone sequence of ordinary hill climbing or steady acceleration knock.

It was observed photographically that while a test engine was run at idling speed, carbon flakes in the combustion chamber glowed a dull red. But as soon as the throttle was opened, the space in the combustion chamber was filled with glowing particles similar to exploding fireworks.

This "ping" or knock followed the dislodging of deposit particles which became hot enough by themselves to ignite the incoming air-fuel charge. Before spark inflamation could occur, the chamber was so alive with small explosions that photos of the phenomenon resembeled pictures of the Milky Way taken by astronomers.

It was pointed out that if carbon deposits never purged themselves, the combustion chamber of an engine would fill up with solid material and require mechanical attention. But in the process of eliminating one problem, the deposit removal introduces another in the form of autoignition.

METALLURGIST GINGERLY MOVES ampoule containing radioactive cobalt wire over casting. Irradiated in a nuclear reactor, the wire is being used by Empire Steel Castings, Inc. to inspect steel castings for defects. Cobalt isotope emits powerful beta particles and gamma rays capable of penetrating through steel up to six inches thick. Photographic film under the casting records defects.

Ceramic Permanent Magnet Replaces Metal With Oxides

AMSTERDAM—Permanent magnets made from a material characterized as a ceramic product with a specific gravity of about 4.8 have been developed by the Phillips Research Laboratory in Eindhoven. Differing greatly in structure and composition from conventional magnet steels, the new material is an oxide and is produced like chinaware by firing or sintering.

In addition to iron oxide, the new magnet material contains barium, an element never before used in permanent magnets. Neither critically short nickel not cobalt is used in the manufacture.

Called Ferroxdure, the ceramic is a hard magnetic material and its magnetism is not easily destroyed. Magnetic Hardness is several times greater in Ferroxdure than in the usual magnet steels.

Magnetic saturation has been reported very low, but this disadvantage has been overcome by increasing the dimensions of the magnet, perpendicular to the direction of magnetization to increase the number of lines of magnetic force. As a result, the new magnets are made so short that they resemble flat disks or plates.

Since it is an oxide and not a metal, Ferroxdure has a low electric conductivity, a billion times lower than that of iron. This is a big advantage when the magnet is exposed to alternating current fields, especially of high frequency. Because of the extreme magnetic hardness, Ferroxdure is also suitable for use when exposed to strong demagnetizing fields.

Phillips is already using the ceramic magnets in their own radio receiver loudspeakers.

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PROBLEM:

Stop Ignition Cables from Burning Out!

This natural gas collector pumping station was out of service at least one day out of every 30, causing a costly loss in gas production. Heat from the gas burning motor charred and cracked the organic rubber insulation on the ignition wires. Leakage of the high voltage spark led to misfiring and failure of the motor. Added to the loss in gas production was the continuous replacement cost of the ignition cables.

SOLUTION:

SILASTIC*, the Dow Corning Silicone rubber.

Ignition cables insulated with Silastic were installed because this Silicone rubber will withstand long exposure to temperatures ranging from —100° to over 500°F.

RESULT:

No Ignition Cable Burn-outs in 2 Years.

The Silastic cables have been in use for 2 years; will probably last the life of the motor. That means reduced maintenance costs, uninterrupted performance and full capacity gas production.

Silastic has high thermal conductivity and excellent dielectric properties over a wide range of frequencies. Silastic remains soft and pliable in sub-zero temperatures, and resilient after long contact with hot oil at temperatures in the range of 400°F. That's why design and production engineers specify Silastic for hundreds of applications where other resilient materials are subject to rapid failure.

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Reaction Forces on Bevel Gear Drives

PAUL F. HORBATT
Formerly with Research Division,
Wright Aeronautical Corporation

IN DESIGNING BEVEL GEAR DRIVES, it is relatively simple to calculate the tangential load on the gear teeth. However, determining the magnitude and direction of the reaction components which act axially and radially is much more difficult. This problem can be complex since there are several variables. Reaction components are a function of the pressure angle of the teeth, the direction of rotation, whether the gear is the driver or driven one, the pitch cone angle γ and the spiral or helix angle ψ.

The size of bearings necessary to properly support the gears are dependent upon these reaction forces. With straight bevel gears, the normal tooth loads can be resolved into axial and radial forces which tend to separate the mating gears. However with spiral bevel gears, larger spiral angles may cause components which tend to move the gears together.

Two charts have been prepared to help the designer calculate the direction and magnitude of the load components: F_a and F_r. Fig. 2 applies to gears having a pitch cone angle γ between 0 and 45 deg. With $\gamma=0$ the pitch surface is a cylinder. Consequently this curve applies to helical gears unless the helix angle ψ is zero (and $H=0$) which becomes a spur gear as illustrated. Fig. 3 is for bevel gears with pitch angles γ in the range of 45 to 90 deg. In the latter case, the gear becomes a face or crown gear. Both of these graphs are based on a gear tooth pressure angle $\phi = 20$ deg. To compute the axial and radial reaction components, the following equations are used:

$$\text{Axial component } F_a = K_a \times W \quad (1)$$

$$\text{Radial component } F_r = K_r \times W \quad (2)$$

Where, W is the tangential force acting on the teeth; factors K_a and K_r are found in either Figs. 2 or 3. Note that these factors are plotted as a function of a helix parameter H. This parameter combines all the variables as follows:

$$H = C\,D\,L\,\psi \quad (3)$$

where,

Helix angle coefficient, $C = +1$ when helix is right hand
$C = -1$ when helix is left hand

Directional Coefficient, $D = +1$ for clockwise rotation viewed from apex.
$D = -1$ for counter-clockwise rotation

Loading Coefficient, $L = +1$ when driving
$L = -1$ when driven

Helix or spiral angle ψ in degrees

For convenience, the positive direction of the coefficients are illustrated on both graphs.

For more precise values of the factor K_a:

$$K_a = \frac{\tan\phi \sin\gamma}{\cos\psi} \pm \tan\psi \cos\gamma \quad (4)$$

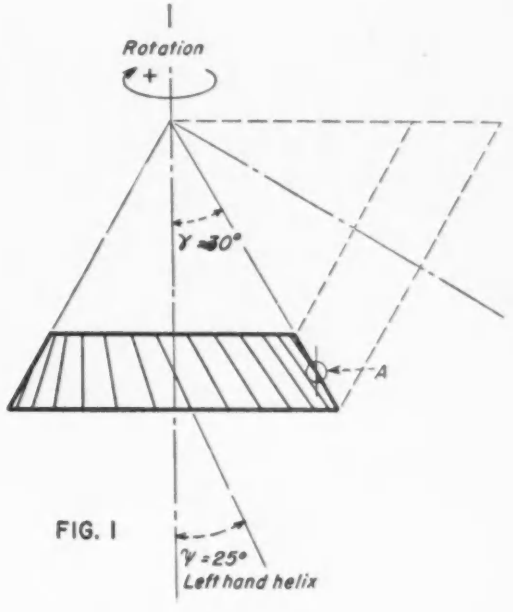

FIG. 1

The $(\pm)$ sign is found from the sign of H in Eq (3). To calculate the radial factor,

$$K_r = \frac{\tan\phi \cos\gamma}{\cos\psi} \pm \tan\psi \sin\gamma \quad (5)$$

For any particular case, the sign used for second term in Eq (5) is opposite to the one used in the corresponding term of Eq (4).

Example: Find the reaction forces acting on the gear shown in Fig. 1. This gear is being driven with a tangential force W of 200 lb. at point A.

From Eq. (3), the helix parameter is:

$$H = (-1) \times (+1) \times (-1) \times (25) = +25$$

Referring to Fig. 2, Line I indicates that $K_r = +0.11$ and Line II shows that $K_a = +0.60$.

Thus the components become:

$$F_a = +0.60 \times 200 = +120 \text{ lb.}$$
$$F_r = +0.11 \times 200 = +22 \text{ lb}$$

In addition, there is the tangential force acting perpendicular to the plane of the paper.

If in this example, the helix angle ψ were changed to a right hand direction, the sign of H would become negative. From Fig. 2 (Line III) the axial factor would be also negative. Thus the axial component would tend to force the mating gears closer into mesh.

(Continued on page 201)

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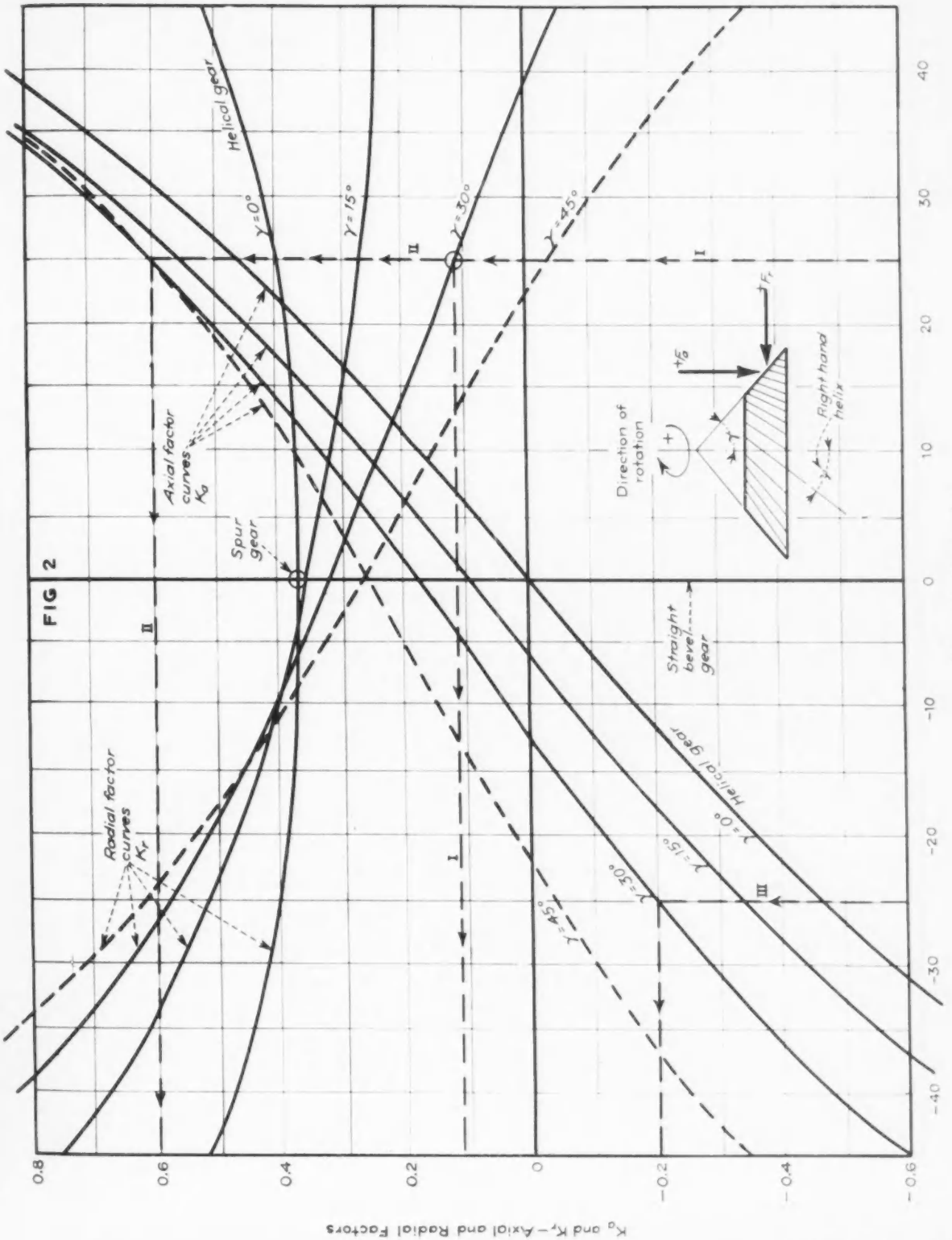
Reaction Forces on Bevel Gear Drives (continued)



(continued on page 203)

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ARMCO 17-7 PH

for lightweight formed structurals

MECHANICAL PROPERTIES of Armco 17-7 PH Compared With Type 301

	ARMCO 17-7 PH SOFT TEMPER		TYPE 301	
	As Supplied (Annealed)	Fabricator Treated (1400 F plus 950 F)	Half Hard	Full Hard
Ultimate Tensile Strength, Psi	130,000 typ. 150,000 max.	215,000 typ. 185,000 min.	150,000 min.	185,000 min.
Yield Strength in Tension, Psi (0.2% offset)	40,000 typ. 55,000 max.	200,000 typ. 165,000 min.	110,000 min.	140,000 min.
Elongation in 2 in., %	30 typ. 20 min.	9 typical 6 minimum	15-18 min.	8-9 min.
Hardness, Rockwell	B92 max. B85 typ.	C45 typ. C41 min.	C-32	C-41
Modulus of Elas. Long.	29,000,000	29,000,000	28,000,000	28,000,000
Density, Lbs. per cu. in. at 70 F.	0.282	0.278	0.29	0.29

Typical Short-Time High-Temperature Properties of Armco 17-7 PH, Soft Temper Fabricator-Treated (1400 F plus 950 F)

Temp. Degrees F	Ultimate Tensile Strength Psi	0.2 Per Cent Yield Strength Psi	Elongation in 2 in. Per Cent	Rockwell Hardness
70	206,500	184,500	9	C 45
300	194,500	174,000	8	—
400	189,000	167,000	6	—
500	180,000	154,000	6	—
600	171,000	141,500	6	—
800	153,000	116,500	8	—

STRENGTH-WEIGHT RATIOS for Armco 17-7 PH Soft Temper
Fabricator-Treated (1400 F plus 950 F)

Strength Property		Ratios Obtained by Dividing Property at Indicated Temperature by Density			
		70 F	300 F	600 F	800 F
Ultimate Tensile Strength, Psi (X 1,000)	Typical	775	700	615	550
	Minimum	665	—	—	—
Yield Strength in Tension, Psi (X 1,000) (0.2% offset)	Typical	720	626	510	419
	Minimum	593	—	—	—
100 Hr Stress—Rupture Strength, Psi (X 1,000)		—	—	583	446
Creep Strength, Psi (X 1,000) (0.1% in 1,000 hr)		—	—	521	180
Modulus of Elasticity, Psi (X 1,000,000)		104	—	—	—

Here is a stainless steel that *has* the best combination of qualities required for lightweight formed structurals.

High Strength-Weight Ratios

At Normal Temperatures:
Strength-weight ratios of Armco 17-7 PH Soft Temper (after hardening) are superior in some instances to the newly introduced non-ferrous light alloys.

At Elevated Temperatures:
Up to 800 degrees F Armco 17-7 PH maintains high strength and *improves* its strength-weight ratios in comparison with the non-ferrous metals, which weaken rapidly above 300 degrees F.

Easily Fabricated

Armco 17-7 PH is supplied in the annealed condition suitable for intricate drawing and forming operations. It is heat treated *after working* by the fabricator. Its high strength is developed through a precipitation-hardening treatment at temperatures of 1400 and 950 degrees F — low enough to avoid serious distortion. On the other hand, High Strength Type 301, the standard stainless structural grade, is supplied in a highly work-hardened condition. Fabrication is difficult and results are often non-uniform.

Other Advantages

Armco 17-7 PH Soft Temper, after hardening, has a yield strength in compression *as good or better than* the yield strength in tension. It has good high-temperature tensile, creep and stress-rupture properties, as well as excellent corrosion resistance.

How Supplied

Armco 17-7 PH Soft Temper is supplied in sheets, strip, plates, angles, special shapes, bars and wire.

Other PH Grades

There is also a "Hard Temper" Armco 17-7 PH and a bar grade, Armco 17-4 PH. For full information write for data on Armco Precipitation-Hardening Stainless Steels.

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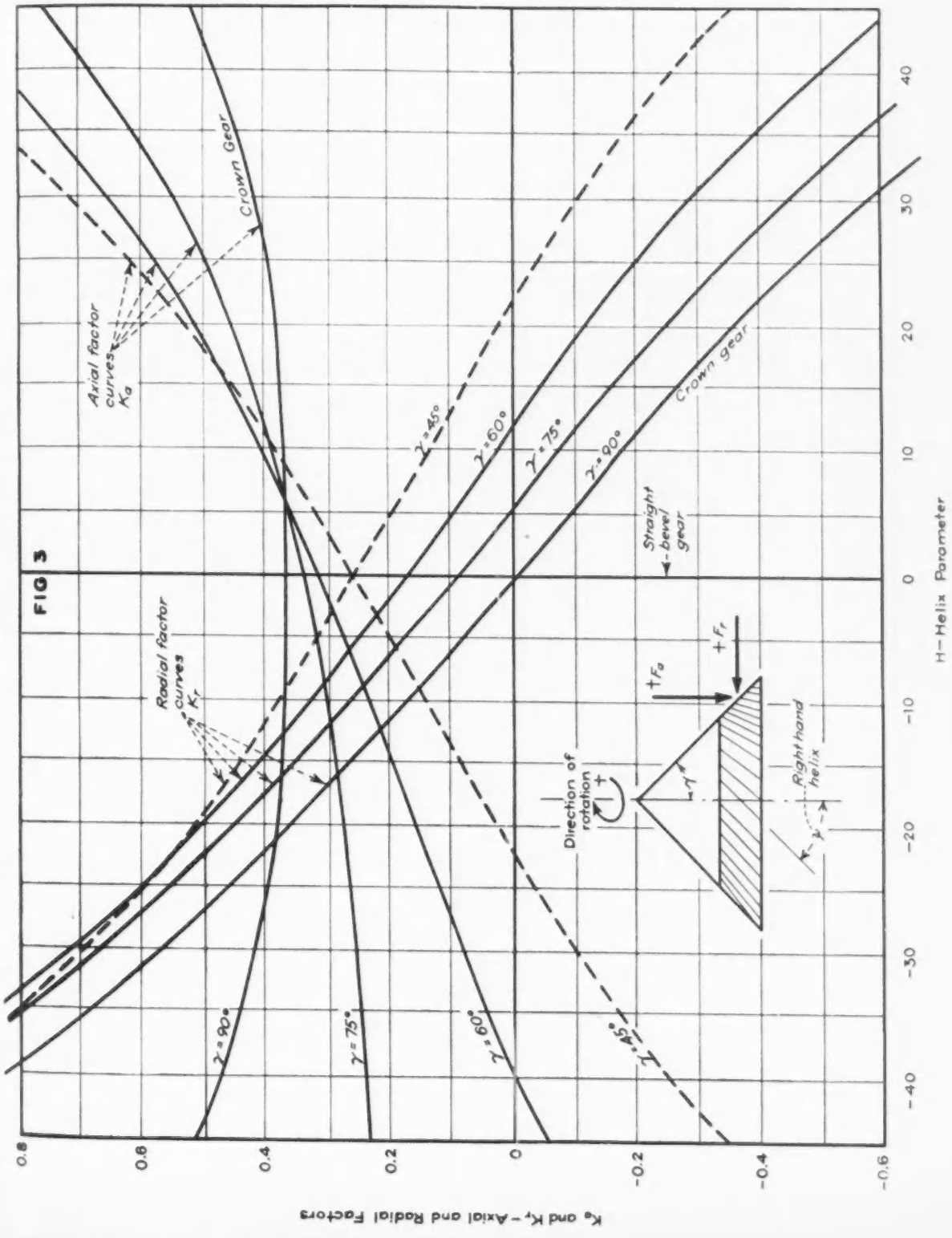
Reaction Forces on Bevel Gear Drives (continued)



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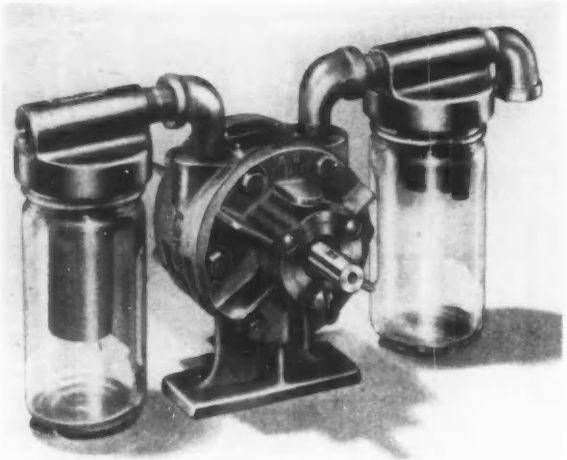
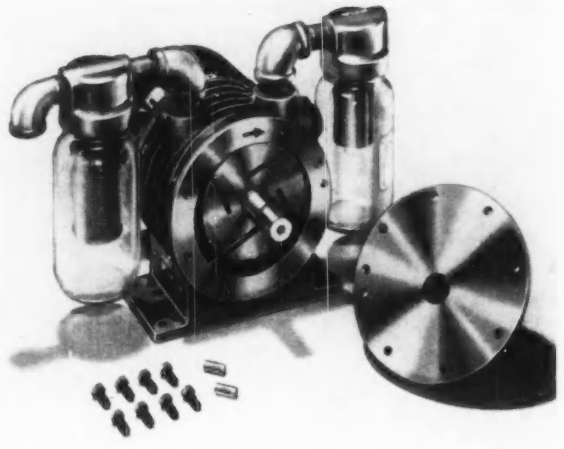


The model 0740 at 1250 rpm gives 3.5 cfm at 20 in. vacuum.



The model 3040 has a capacity of 24 cfm at 20 in. vacuum.

Rotary Air Pump Requires No Lubrication

These rotary air pumps are specifically designed to produce moderate vacuum or air pressure with large air volume in proportion to the horsepower required. A rotor and four sliding vanes are the only moving parts. Centrifugal force holds the vanes against the housing, giving a tight seal, with the vanes taking up their own wear automatically. In explosive atmospheres these pumps are explosion-proof.

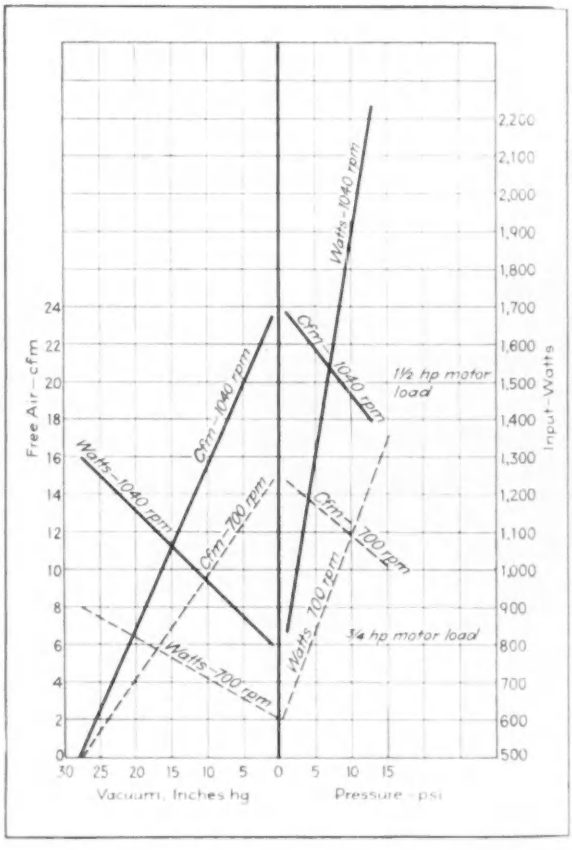
Called the "oiless" pumps by the manufacturers, these pumps have: (1) ballbearings that are greased and sealed for life, and require no further lubrication; (2) vanes of self-lubricating carbon, with automatic takeup for wear, and are not affected by atmospheric conditions or temperature changes; (3) the pumping chamber is entirely dry, with a ventilated space between the bearing and the pumping chamber to keep the pump free of hot oil vapor; (4) no metal-to-metal contact on working parts; (5) no body or end plate spacer gaskets, and no shaft seal.

The applications are limited to the range of 15 to 20 vacuum inches of mercury, and when used for pressure, from 10 to 15 psi is maximum.

The model 0740, $6\frac{5}{16}$ in. long, having $\frac{1}{4}$ bhp, operates at 1250 rpm and has a capacity of 3.5 cfm, at 20 in. vacuum or a pressure of 10 psi. The model 3040, $12\frac{5}{16}$ in. long, with $1\frac{1}{2}$ bhp operates at 1050 rpm and has a capacity of 24 cfm at 20 in. vacuum or a pressure of 10 psi.

Ten sizes of V-belt drives are available as component equipment. This type of drive will give slower pump speeds, quieter operation, and longer life. These pumps may be used for feeding paper, lightmetal or plastics into automatic machines, and for packaging machinery.

Shown in the illustrations are the model 0740 pump, and model 3040 pump with the end plate removed. The graph shows the operational characteristics of the model 3040.



Gast Mfg. Co., Benton Harbor, Michigan

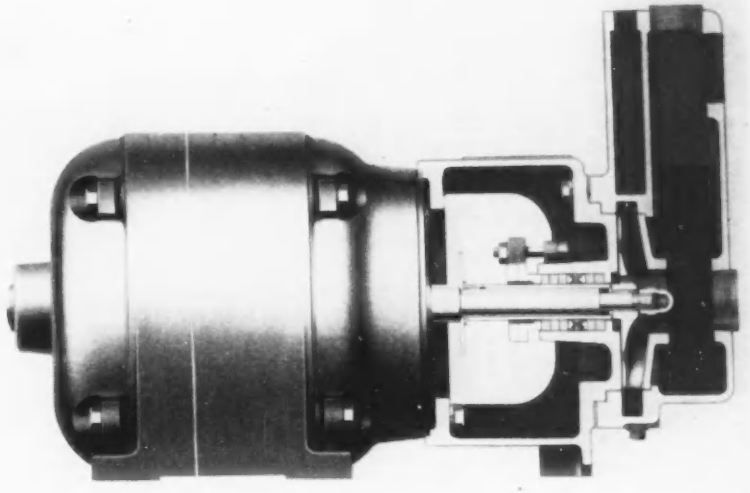
Self-Priming Pump Capacities to 800 Gpm

A new line of self-priming motor pumps has been designed for pumping applications under suction lift where the presence of air or vapor makes it impractical to use the conventional centrifugal pumps. The pumps may be used in process and bulk station applications, for mine drainage, bilge pumping, sump draining and irrigation service.

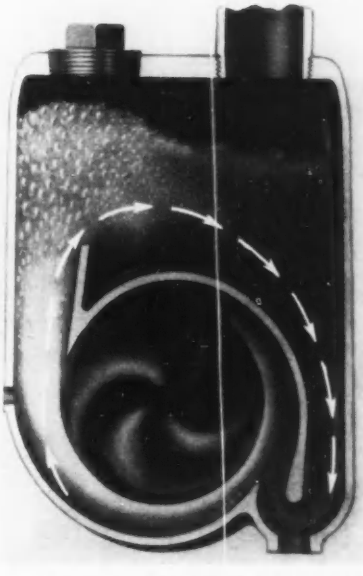
Conventional centrifugal pumps that are unable to eliminate appreciable volumes of air or vapor when operating under suction lift, lose prime when such vapor is present. To reestablish prime, it becomes necessary to fill the suction line and casing before starting. The new self-priming motorpump overcomes this disadvantage by means of recirculating liquid trapped in the casing. The pump impeller discharges through two passages into a discharge chamber. During priming the upper passage discharges a mixture of vapor and liquid into the discharge chamber. Here the vapor separates from the liquid and passes out the discharge pipe. The remaining liquid reenters the impeller through the lower passage to mix with more vapor drawn in from the suction pipe and is separated from the liquid in the same manner. When the suction pipe is finally filled with liquid and the pump is primed, flow through the lower passage reverses and both passages act as normal pump discharges. During normal pump operation there are no recirculation losses and thus no need of valves to cut off recirculation. No flap valve is used because the pump casing is so proportioned that sufficient liquid is trapped on shut down to insure priming when the unit is re-started.

The pump is built in sizes from $\frac{1}{4}$ to 25 hp, with capacities up to 800 gpm and a head up to 180 ft.

Ingersoll-Rand Co., Dept. CAM, 11 Broadway, New York 4, N. Y.



THE STUFFING BOX may be equipped with mechanical seals or conventional packing except on KRVSP units which are available with mechanical seals only. With mechanical seals, on clean liquid service, fluid for the seal chamber is provided from the casing. For dirty liquids, an external grease seal is used. A shaft seal prevents wear of the motor shaft. These units range in size from 17 19/32 x 14¼ x 8¾ in. for the smallest, up to 35¼ x 27⅞ x 17½ in. for the largest. Weights from 110 to 625 lb with motor.



THE DOUBLE VOLUTE CONSTRUCTION recirculates the liquid vapor mixture during the priming period until the impeller chamber is filled with the liquid. The self-primers may be converted to regular centrifugal pumps by changing the casing and suction piece.

NOW THAT PRIMING is completed, liquid is discharged from the impeller chamber through each volute into the discharge chamber. These pumps are available mounted on ball bearing equipped cradles to be driven through a coupling by a motor, engine, or turbine.

CONTINUED ON PAGE 206

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Electron Microscope Has High Magnification

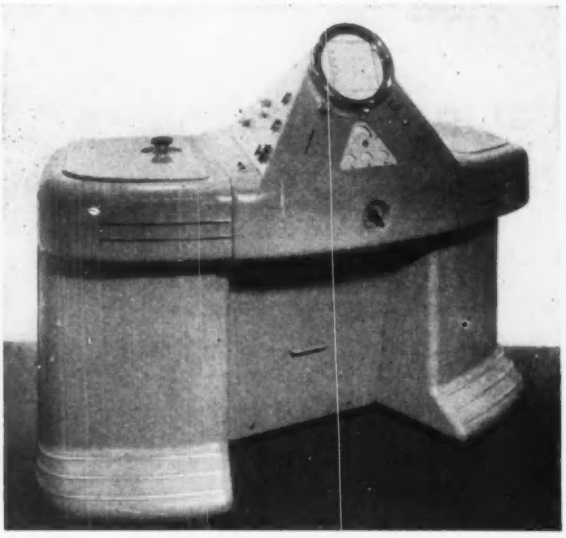
The screen magnification of this new electron microscope is continuous from 1,000X to 60,000X, and the instrument is capable of producing micrograms of 30 Angstroms resolution or better. Accelerating potentials of 40, 60, 80 and 100 kilovolts are available. The microscope has a beam oscillator for rapid determination of exact focus, eliminating the necessity for a series of exposures. A through focal series is obtained by means of an additional fine focus control.

The microscope has a short column, which minimizes the effects of vibration, and permits high enlargement because of good lens design. A short focal length projector lens minimizes spherical aberration, while image size is controlled by an intermediate lens system. The large bore objective pole piece also helps to reduce spherical abberation and aids in the centering of the objective aperature. Electromagnetic beam alignment system is operated by fingertip controls.

The unit has large field, and permits recording in a single photograph, areas which might otherwise require a mosiac of six individual sections. A roll film camera is employed, using standard 35 mm high contrast film, and allowing grain-free enlargements to 12X or better.

The microscope has a retractable breech-type gun assembly which uses a preset filament. The console has all normal controls readily accessible. It is entirely self-contained, has no external pumps and no liquid air traps. It measures 5 ft in length, 4 ft in height, and 3 ft in depth. Approximate total weight uncrated is 1,200 lb. No special mounting precautions are necessary due to special features of design which minimize the effects of ordinary vibration.

The unit requires three-phase, 4-wire a-c 220/380 v, 60 cycle supply, with neutral wire and the usual equipment ground lead. Line voltage variations of 5 percent are permissible. The power consumption is 2½ to 3 kva. Conversion transformers are available for 230 v delta or 120/208 v star systems.



Cooling water of approximately 60 F and flowing at a rate of two quarts per minute at 15 to 20 lb psi is required. Provision must be made for handling discharge water.

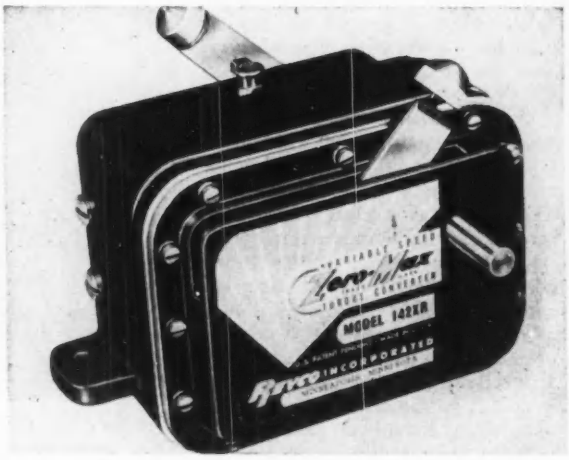
North American Phillips Co., Inc., 750 S. Fulton Ave., Mt. Vernon, N. Y.

Instant Reverse on Torque Converter

The latest Zero-Max variable speed torque converter, known as the model 142XR, has variable speed from 0 to ½ input speed in either direction. The speed and reverse controls are separate levers and the transmission can be reversed at any time, with or without load on the output shaft. The reverse lever moves through neutral, and in this position the output shaft is free and can be manually rotated in either direction. The speed control and direction control levers operate in the same plane.

The model 142XR is rated at ½ hp at 350 rpm with 1,725 rpm motor input speed. The output speed is infinitely variable from 0 to maximum ½ input speed in either direction. The load rating is 20 in.-pounds. The unit weighs 6 lb, and the dimensions, excluding shafts, are 6 in. x 3½ in. x 5¼ inches.

Suggested uses are for: turntables, feeders, conveyors and all kinds of laboratory, medical and industrial equipment and practically any application where change of both direction and speed are required. Several other models are available, either with or without reverse in 15 and 20 in.-lb ratings. Special direction, mounting, arrangements, and other special constructions can be supplied. Other uses for the smaller models include: fans, automatic washers, stoker blowers, mixers, blueprint machines, and small machine tools.

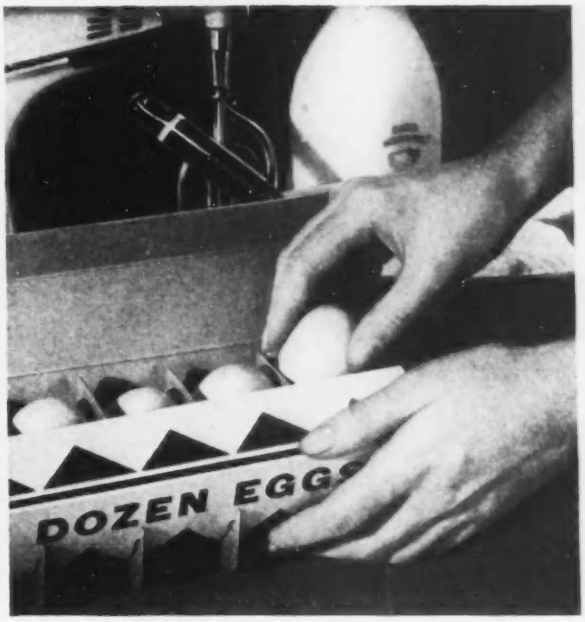


Revco Inc., 2 E. Franklin Ave., Minneapolis 4, Minn.

CONTINUED ON PAGE 208

How would YOU solve these two problems?

VISCOSITY CONTROL is important to Fuller Brush manufacture. Special sealing compound makes their handles stay put. It's applied by expensive equipment. If the equipment is started before the compound is fluid, the automatic machinery will be severely damaged. Now a *low-cost* Fenwal THERMOSWITCH thermostat prevents damage by starting the motor *only* when viscosity is right.



SPOILAGE FROM OVER-HEATING would prove costly to egg producers if water in Paden's Whirl-A-Way egg washer got too hot. Accurate temperature control, under extreme moisture conditions, was called for. *Only* a temperature-sensitive, adjustable, moisture-proofed Fenwal THERMOSWITCH thermostat installation met *all* the requirements at reasonable cost.

A FENWAL THERMOSWITCH CONTROL may solve your problem, too. Its external single-metal shell expands or contracts *instantly* with temperature changes, making or breaking enclosed electrical contacts. Compact, hermetically sealed, highly resistant to shock and vibration, Fenwal THERMOSWITCH units have solved hundreds of problems.

SEND FOR THIS NEW CATALOG for complete explanation of the unique THERMOSWITCH unit. Also ask for more detailed, illustrated discussions of the problems above. Fenwal engineers will be glad to help you solve your temperature control problems involving heat, humidity, vapor level, radiant heat, pressure and other variables. Write Fenwal, Incorporated, Temperature Control Engineers, 23 Pleasant Street, Ashland, Mass.

Fenwal

THERMOSWITCH®

Electrical Temperature Control and Detection Devices

SENSITIVE . . . *but only to heat*

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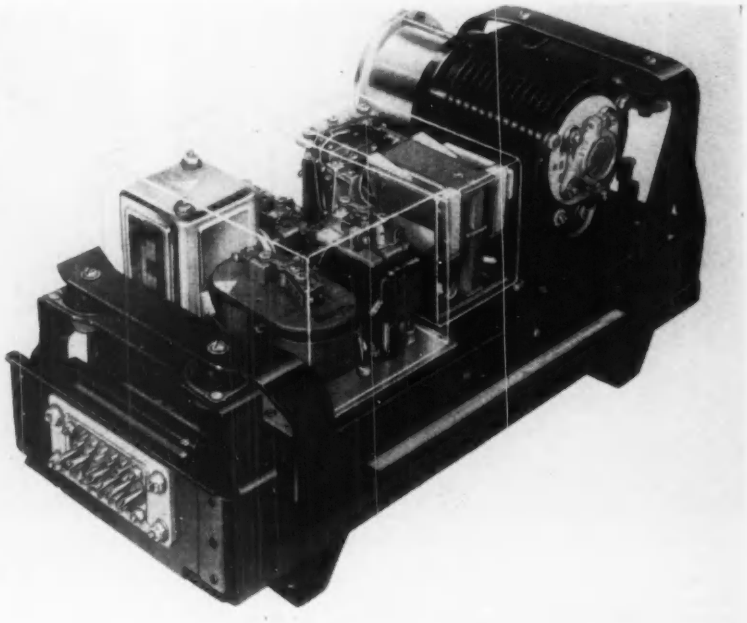
Standard Control System for Aircraft Generators

A standard electrical control system has been developed for aircraft generators that can be installed on many types of aircraft and can be physically and electrically interchangeable with systems of other manufacturers.

This standard 28 v d-c system, designated GC 34-1, is designed to continuously control and protect generators under rugged altitude and temperature conditions. This system is effective at barometric pressures ranging from 30 inches of mercury down to 3.5 inches (approximating a 50,000 ft altitude), temperature ranges from —67 F to 160 F, a relative humidity up to 100 percent, exposure to airborne sand and dust particles, salt-laden moisture, fungi, and aircraft vibration.

The system offers protection against selective overvoltage, feeder ground fault, generator ground fault, reverse polarity, reverse current, and pull-down voltage. Features of the GC 34—1 system include stable and long-life voltage regulators, high interrupting capacity contactors, accurate paralleling, simplified trip-free resetting, and manual or remote setting.

The unit is mounted on a panelized mounting tray that can be easily installed and serviced. Only one external cable connection is required, and wiring is further simplified by mounting the entire system in one spot. The system has minimum vulnerability by combat damage, as it can be protected by armor plate.



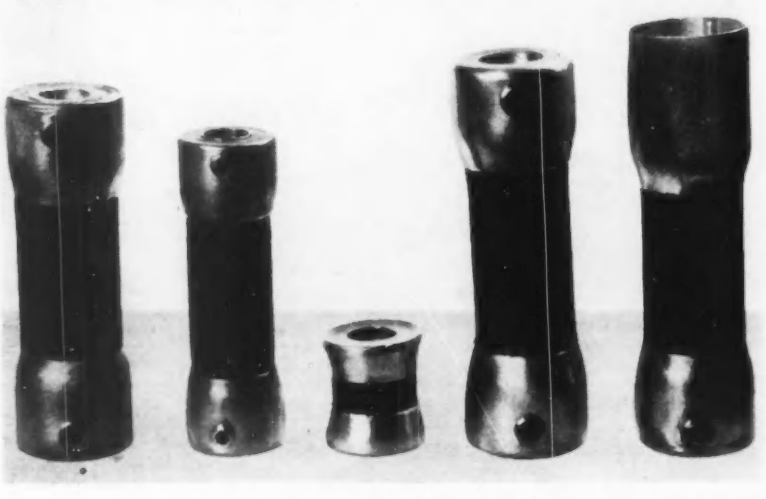
Other aircraft equipment that operates with the panel and makes up the complete generator control system are an aircraft engine-driven generator, main contactor, two 250 millivolt shunts, and generator switch.

Jack & Heintz, Inc.
17600 Broadway, Cleveland 1, Ohio

Flexible Coupling Has Increased Torque Range

Increased ranges of torque capacities, torsional resilience control, and added flexibility are some of the new features of a new flexible coupling. In addition to their use on oil burners, the couplings are used in pumps, compressors, light machinery drives, and power lawn mowers. Reinforcement of the flexible element, and new design specifications are said to have increased torque capacities.

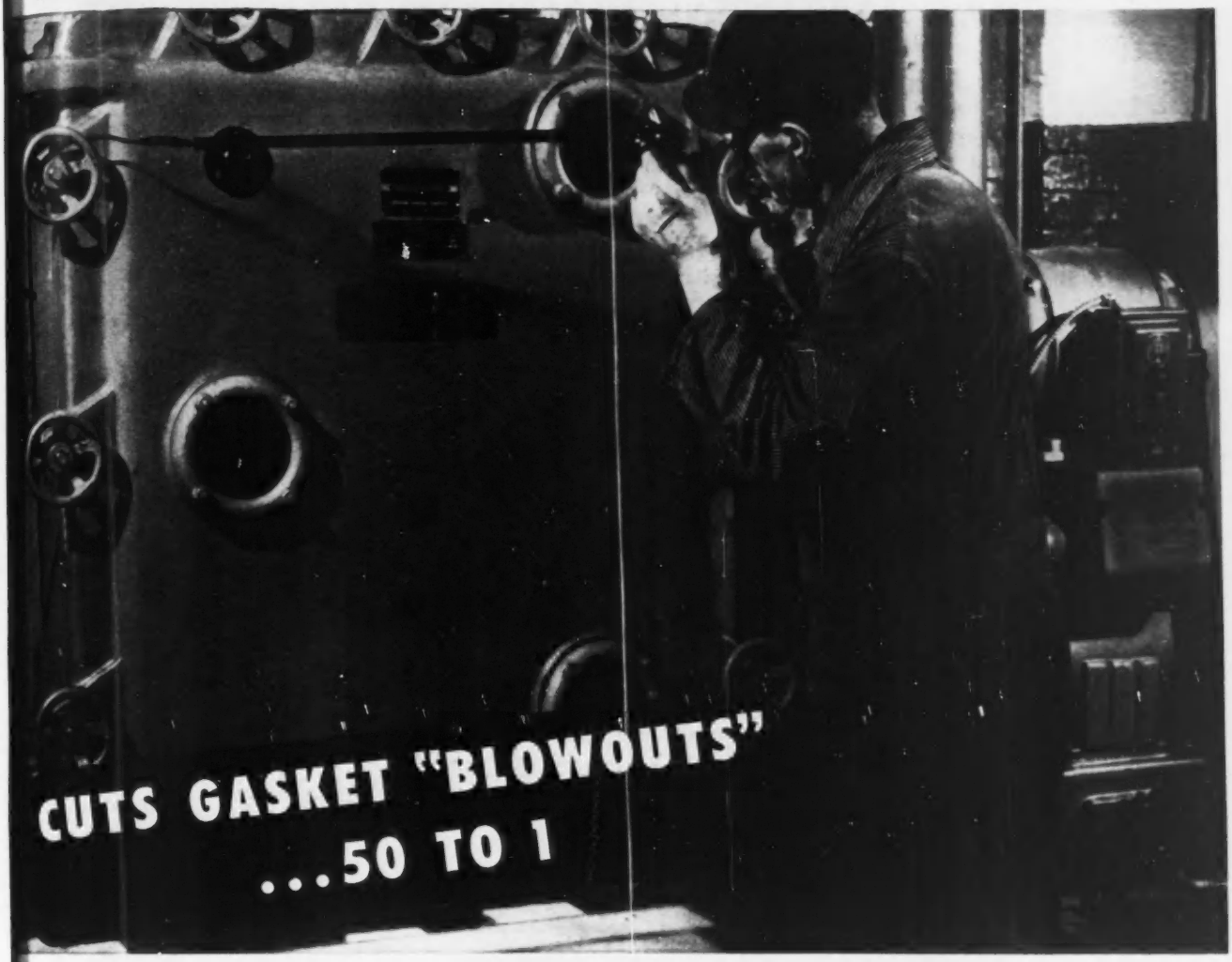
In the 25 to 124 w range, overall lengths of 1 in. to 4 in. and bores of $\frac{3}{16}$ in., $\frac{1}{4}$ in., $\frac{5}{16}$ in., $\frac{3}{8}$ in., $\frac{7}{16}$ in. and $\frac{1}{2}$ in. are available; in the 125 to 248 w range, overall lengths of 1-$\frac{3}{4}$ in. to 7-$\frac{7}{8}$ in. and bores of $\frac{1}{4}$ in., $\frac{5}{16}$ in., $\frac{3}{8}$ in., $\frac{7}{16}$ in., $\frac{1}{2}$ in., $\frac{9}{16}$ in., $\frac{5}{8}$ in., and $\frac{3}{4}$ in. are available; and in the 249 to 550 w range, lengths of 2-$\frac{1}{2}$ in. to 7-$\frac{7}{8}$ in. and bores of $\frac{7}{16}$ in., $\frac{1}{2}$ in., $\frac{9}{16}$ in., $\frac{5}{8}$ in., and $\frac{3}{4}$ in. are available, all at 1750 rpm.



The Guardian Products Corp., 1215 E. 2 St., Michigan City, Ind.

CONTINUED ON PAGE 210

QUAKER *Production-eered** PACKING



QUAKER RUBBER PACKING

GIVES LONG, CONTINUOUS SERVICE . . . FREE FROM HIGH REPLACEMENT COSTS

Gasket "blow out" trouble used to run high on this high pressure creosoting cylinder. Working continuously against 212° F. temperature and 200 lb. pressure, cylinder door gaskets had to be replaced about every three weeks This meant down-time, lost production, soaring costs.

Quaker "Production-eered" packing solved this knotty problem. Tough, resilient, built to stand up and take a beating, Quaker gaskets outlast previous gaskets by 50 to 1! This creosoting cylinder is now a model of efficiency.

Just one more example of how Quaker "Production-eering" is boosting efficiency of all types of equipment. Let an experienced Quaker representative show you how you can cut down-time, boost production by making Quaker "Production-eered" packing, hose, belting and molded rubber products an integral part of original equipment.

***Production-eering**—Every Quaker Industrial Rubber Product is "Production-eered"—engineered to provide maximum life, efficiency and production on each type of installation. Quaker "Production-eers" are ready to recommend the right rubber product for the job. For timely production tips get the new free booklet on "Production-eering for Industry." Write today.

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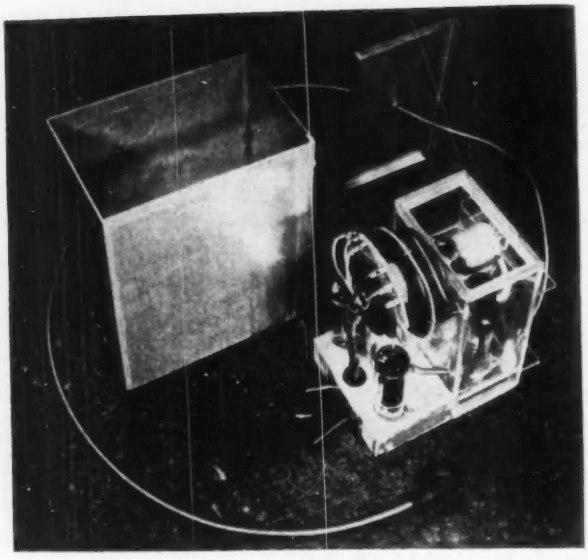
Miniaturized High Voltage Power Unit

A new low-cost, regulated high-voltage d-c power supply unit for use with cathode ray and Geiger counter tubes is a miniaturized unit that is light in weight, operates at temperatures from minus 30 C to 80 C and can be adapted to airborne and radar equipment.

Input is 315 v d-c, 50 miliamp; output is 18 kv d-c, 150 microamp maximum. Taps may be provided at lower voltages to supply intermediate accelerating anodes. The a-c ripple averages 1 percent. The unit is built to withstand 21 kv at 50 percent humidity.

Four electronic tubes are used; one 5763 RF oscillator, one 6AQ5 regulator, and two 1B3GT high voltage rectifiers. Unit is housed in a metal case and is shielded for RF radiation. Leads are brought out to facilitate connections to cathode ray or Geiger Counter tube and to low voltage power supply.

A Ferroxcube core is used in the high voltage transformer to obtain high efficiency and compactness. Dimensions of the power supply are: 6 in. wide, 5¼ in. high, 3½ in. deep, and weight 2½ pounds.

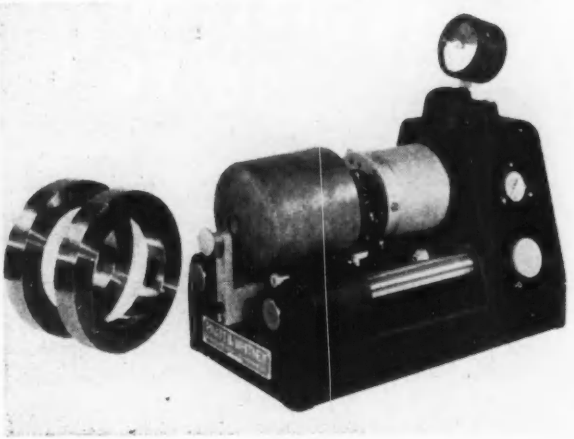


North American Phillips Co., Inc., 750 S. Fulton Ave., Mt. Vernon, N. Y.

Special Gage Checks Compressor Housings

A special Air-O-Limit gaging fixture has been designed for checking the bores of refrigerator compressor housings made of deep drawn sheet steel. They have an average internal diameter tolerance of 0.002 inch, and a maximum out-of-round tolerance of 0.015 inch. The gage checks the housing bore for average diameter at several points along the entire length of the internal wall.

The gage has a ball bushing slide on which the housing is located from its outside diameter. This slide is also used to move the housing on and off the gaging plug. The gaging plug has six cartridge-type gaging nozzles that feed from one gaging unit. The amount of air that escapes from these nozzles combines to give an average diameter reading on the indicating meter. The dial on the side shows line pressure. The indicating meter is calibrated with full scale of 0.016 inch.



Pratt & Whitney, Niles-Bement-Pond Co., Div., West Hartford 1, Conn.

New Compound Developed for O-Ring Seals

A new O-ring seal compound developed for use in farm tractor hydraulic systems, has good high and low temperature properties and may be used with almost any petroleum-based hydraulic fluid.

Created especially for use in the hydraulic lifting systems of tractors, the compound is based on hycar rubber. Hycar is inert to most oils, greases, chemicals, and has good shock and abrasion resistance. Because of the variety of fluids that tractor operators might use, an O-ring seal was needed that could be used with any hydraulic fluid. The manufacturers claim that this hycar compound also is the first acceptable O-ring material for many industrial applications.

O-rings are often used as seals for couplings, compressors, nozzles, and a variety of other such installations. The sealing action takes place as internal pressure forces the O-ring against the wall of a properly designed groove.

Hycar rubber may also be used as a synthetic resin and modifier, for coating or impregnating, and adhesive

B. F. Goodrich Chemical Co 324 Rose Bldg., Cleveland, Ohio

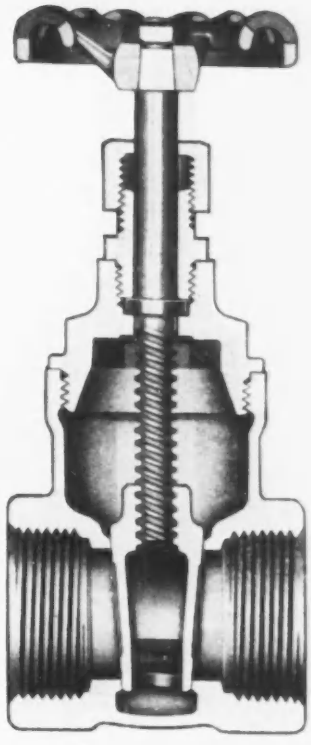
CONTINUED ON PAGE 212

Big help on Piping design ...your CRANE Catalog

Big help in more ways than one, too. Your Crane Catalog saves specifying time—everything you need is carefully cataloged and cross-indexed for quick and easy selection. And "everything" at Crane means the world's most complete assortment of valves, fittings, pipe, and piping accessories.

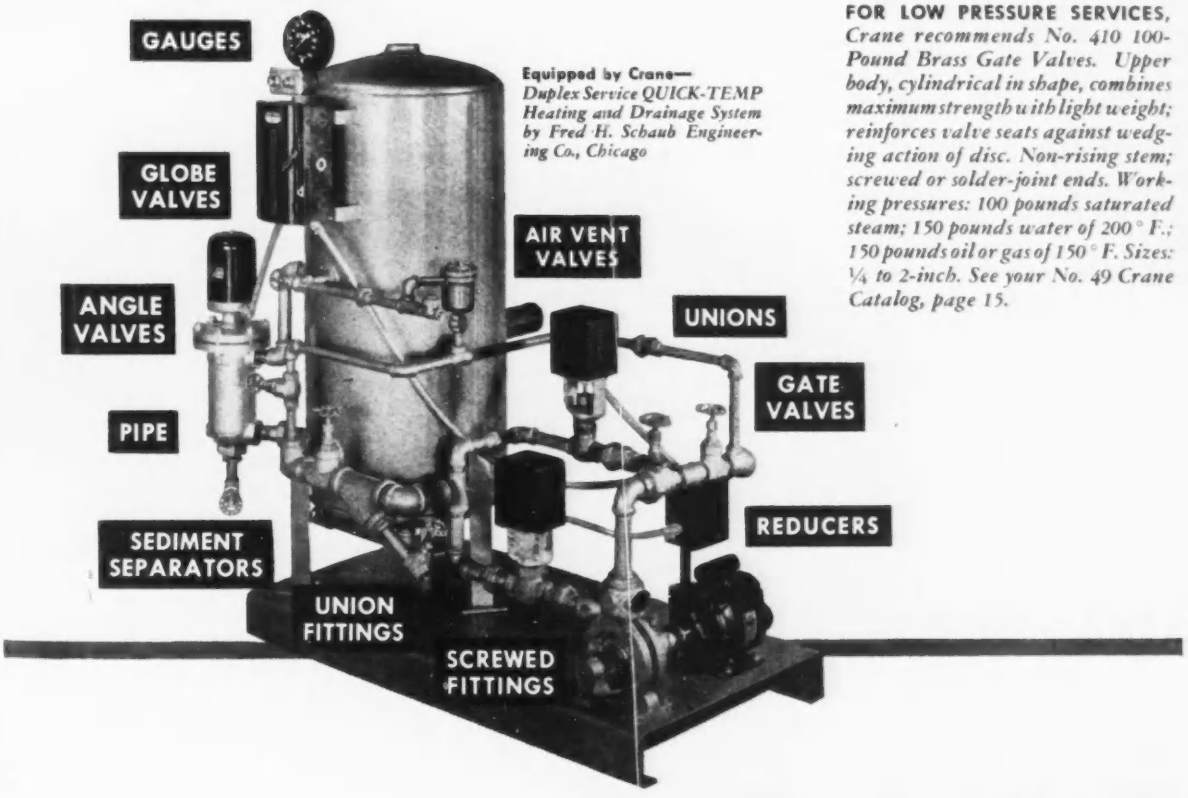
Making Crane your single source of supply simplifies other piping procedures, too—ordering, storekeeping, and final product assembly, for example. Most important—especially today—your product has added customer appeal when all piping is Crane. For machinery buyers know from experience that Crane Quality and "top quality" are one and the same.

CRANE CO., 836 S. Michigan Ave., Chicago 5, Ill.
Branches and Wholesalers Serving All Industrial Areas



FOR LOW PRESSURE SERVICES, *Crane recommends No. 410 100-Pound Brass Gate Valves. Upper body, cylindrical in shape, combines maximum strength with light weight; reinforces valve seats against wedging action of disc. Non-rising stem; screwed or solder-joint ends. Working pressures: 100 pounds saturated steam; 150 pounds water of 200° F.; 150 pounds oil or gas of 150° F. Sizes: ¼ to 2-inch. See your No. 49 Crane Catalog, page 15.*

FOR A BROADER SELECTION OF BETTER PIPING ...LOOK TO THE CRANE LINE



Equipped by Crane— *Duplex Service QUICK-TEMP Heating and Drainage System by Fred H. Schaub Engineering Co., Chicago*

EVERYTHING FOR EVERY PIPING SYSTEM

CRANE

VALVES • FITTINGS • PIPE • PLUMBING AND HEATING

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Miniaturized Plug-In Servo Amplifiers

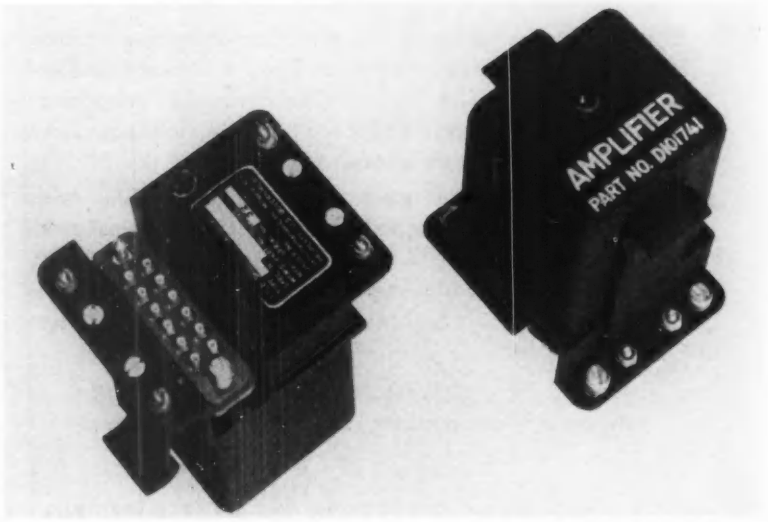
Designated as type SA104H and type SA112H, these amplifiers are the latest models in a series of 400 cycle servo amplifiers featuring a hermetically sealed, oil-filled packaging technique. This packaging design offers: greater heat dissipation and elimination of hot spots; longer tube life; greater resistance to vibration and shock; and a saving in space.

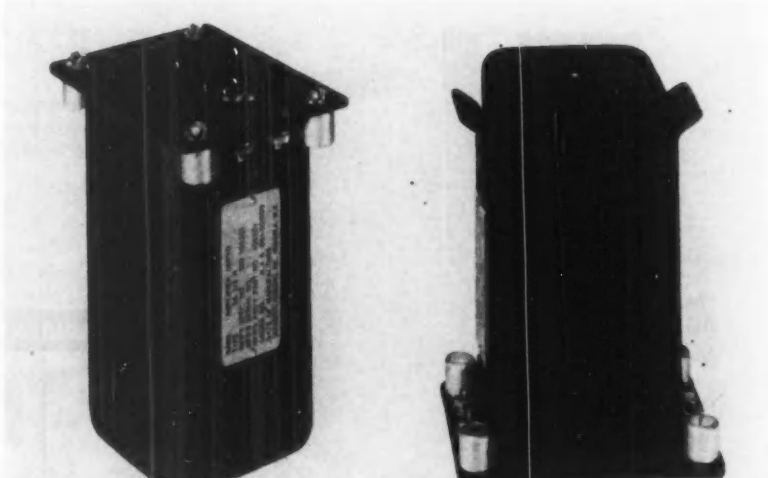
The type SA104H model supplies an output of 9 w at 115 v, and the SA112H, an output of 3 w at 30 volts. The type SA104H shown at top has been primarily designed for use in high performance servo loops and incorporates a derivative control network. Power supply PS108 is available for use with the SA-104H. The SA112H amplifier is intended for use in analog computer servo loops and is designed for velocity damping, furnished by a tachometer generator. Power supplies PS122 for one amplifier and PS114 for three amplifiers can be furnished for use with the SA112H.

These amplifiers have been designed as miniaturized, plug in units, in which all the electronic elements required for one function in a control system are packaged together. Miniaturization of the amplifiers has resulted in savings in spatial requirements. The SA104H measures $2\frac{7}{8}$ x $3\frac{3}{4}$ x $4\frac{9}{16}$ in. high and weighs $2\frac{7}{8}$ pounds. The SA112H measures $2\frac{1}{4}$ x 3 x $4\frac{1}{8}$ in. high and weighs $1\frac{1}{2}$ pounds.

The amplifiers may be mounted in any desired position, and are designed for continuous operation over an ambient temperature range of —65 to 175 F, and at all ambient pressures from sea level to 60,000 feet.

Servomechanisms, Inc., Post & Stewart Aves., Westbury, L. I., N. Y.





NONCORRODIBLE PIPE FITTINGS for the oil fields are fabricated from durable Tenite plastic, the same material now used for oil field piping. Threaded or slip-sleeve, the fittings are produced in a variety of sizes and shapes. Slip-sleeve couplings can be quickly installed and permanently bonded in tenite line by use of a cement and thinner having an affinity with the plastic. The light weight and high impact strength of tenite make the fittings easy to handle. Installed, these long-wearing tenite parts prove resistant to weather and soil conditions. Tennessee Eastman Co., Kingsport, Tenn.

A SNIFFLE TYPE OF FLOW CHECK VALVE for use in fuel purging systems, permits the flow of air in both directions, the outflow from the tank at a predetermined restricted setting, and a nearly unrestricted inflow to satisfy conditions of vacuum relief. Two sizes in production are: the $1\frac{1}{2}$ in., size, for flows from 1 to 6 lb per min, and the 3 in. size for flows from 2 to 12 lb per minute. To meet low temperature and icing conditions, the valves have heating elements and overheat thermostats. Power required is 24 v d-c. Pacific Airmotive Corp., 2490 N. Hollywood, Burbank, Calif.

KNOWN AS THE TYPE 502 c, a tiny $\frac{1}{4}$ in. dia, "shirt stud" ceramic capacitor is used for coupling UHF circuits and other electronic equipment. The capacitors are available in values up to 22 mmf at 500 v d-c working. Sprague Electric Co., N. Adams, Mass.

CONTINUED ON PAGE 214

Shunt Changes Electrometer to Micro-microammeter

The new model 2001 electrometer shunt, for use on the model 200 vacuum tube electrometer made by this company, gives quick conversion of the electrometer to a micro-microammeter.

The model 2001 shunt is an aluminum cylinder containing a resistor. Available in any of seven standard resistance values, it gives direct current readings from 10^{-6} to 10^{-13} ampere. When clipped on the guard ring and HI terminal of the electrometer, the resistor is connected across the electrometer input. The shunt clips over the guard ring and requires no other connections.

Exacting measurements of current, such as insulation leakage, and in ion chambers and photoelectric cells, can be made by the electrometer and electrometer shunt.

The electrometer may be used wherever a self-contained d-c voltmeter with a high input impedance is required. Present applications include measuring voltage of charged capacitors, measuring piezoelectric potentials, measuring d-c amplifier and fm discriminator potentials, and in measuring capacitor and insulation leakages.

The resistor is protected from dust and handling by the case and insulating plates at each end.

Keithley Instruments, 3868 Carnegie Ave., Cleveland 15, Ohio

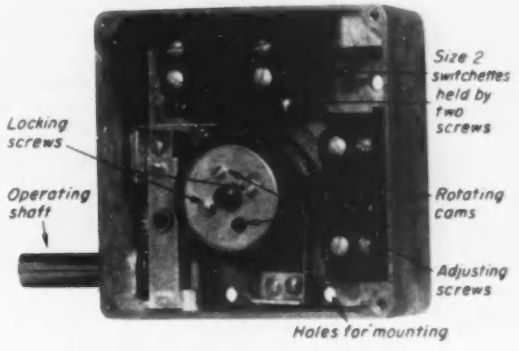
Rotating Type Limit Switch for Reversing Service

A new rotating-type limit switch has been designed for application where reversing operation is to be co-ordinated with the number of revolutions of a motor-shaft or driven equipment. The new switch can be used to control motor-operated doors and windows, valves on machine tools, baling operations, travel limits on machinery, and for other applications.

The switch consists of two size 2 switchettes each having one normally open and one normally closed circuit. Switch units are operated independently by cams rotated through a worm and gear reduction from a shaft extending outside the case.

According to the manufacturers, adjustment of the limit switch is accomplished by loosening two clamping screws, turning slotted adjusting pins (one for each cam) to the desired setting, and then retightening the clamping screws. It can be adjusted to operate from 4 to 110 turns of the driving shaft with 5 turns over-travel in either direction. Unlimited over-travel is possible without damage to the switch.

All parts are accessible for installation, adjustment, and maintenance. The standard form of the new switch is housed in a zinc die-cast case with removable cover, and cams are easily set by adjusting the two screws. Also available are water-tight and explosion-proof forms in cast-iron cases. A bracket is available for foot mounting.



A $\frac{3}{4}$ in. pipe tap conduit opening located between two switch units gives access to contact terminals located at the top of the switch units. Wires do not cross any moving parts. To facilitate the replacement of old switches, the new model is similar in size to the older forms. Dimensions are $4\frac{9}{16}$ x $4\frac{11}{32}$ x $2\frac{3}{32}$ in., with the operating shaft extending $1\frac{1}{2}$ inches.

General Electric Co., Schenectady 5, N. Y.

CONTINUED ON PAGE 218

UNIVERSITY OF MICHIGAN LIBRARIES

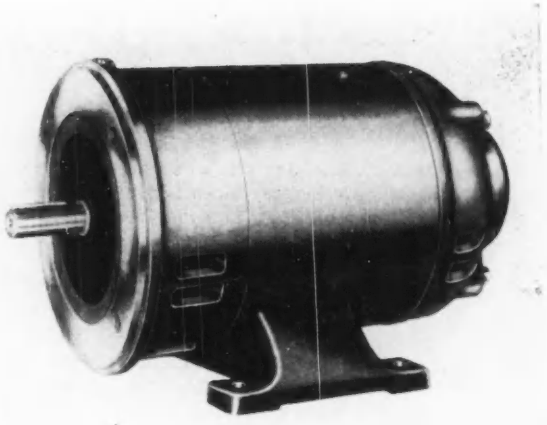
NEMA Frame, Face Mounted, Integral Hp Motors

Built in standard NEMA frames, this new line of "C" face mounted, integral HP motors has units in single phase, with ratings through 3 hp at 3,450 rpm, and in polyphase, with ratings through 5 hp at 3,450 rpm.

Two basic varieties are available: Horizontal, as shown in the illustration; and Vertical, similar to the one shown, except without a mounting base. It is equipped with a canopy. Both varieties are dripproof, equipped with heavy-duty ball bearings, and suitable for continuous-duty operation on applications such as water pumps, sewage pumps, machine tools where vertical operation is required, and by other general-purpose application.

Special features of this line include: on the single-phase units, a totally enclosed dust-proof, dirt-proof external switch housing which prevents foreign matter from lodging between the contacting points; and condensers mounted within the motor base to minimize handling damage.

The Hoover Co., 360 N. Michigan Ave., Chicago 1, Ill.



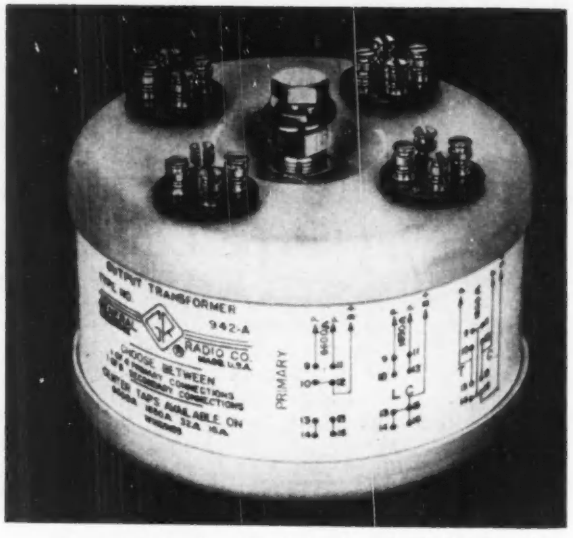
High Power Toroidal Output Transformer

Combined in this new type 942-A output transformer are: good frequency response, low distortion, high power-handling capacity, flexibility of impedance ratios, and a high degree of astaticism. In addition to its use in regular audio amplifiers, the transformer may be adapted for use in high power modulators; and in amplifiers for electronic musical instruments, industrial uses, and constant voltage audio distribution systems.

Eighteen impedance ratios can be obtained covering a wide range of values. The primary windings can be separated as required in certain single-ended push-pull amplifier circuits. Leakage reactance between primary sections is small to give minimum distortion from switching transients in conventional push-pull circuits. Tight primary to secondary coupling permits feedback with low phase shift.

The transformer has a continuous power rating of 90 w and is capable of handling peak powers of more than 100 watts. At the continuous power rating, the transformer distortion is 1 percent or less above 30 cycles under normal operating conditions. The upper limit is between 50 and 100 kc, depending upon the connections used.

The type 942-A output transformer weighs 7 lb. and measures 3-$\frac{3}{4}$ in. high with a 5-$\frac{1}{2}$ in. over-all diameter.



General Radio Co., 275 Mass. Ave., Cambridge 39, Mass.

Capnut Gives Positive Locking and Moisture Protection

A lock nut known as the caploc gives positive locking, and affords a protection against moisture and corrosive action that destroys bolt ends and make a nut non-removable. It also gives protection to the bolt itself where abrasion is possible.

The caploc consists of high quality, heat-treated alloy spring steel insert within the cap. This insert acts purely as a locking device. The load is taken entirely by the caploc nut body. The insert is eliptical in shape but is forced back into the round by the bolt as it passes through. The locking power develops by the pressure exerted on the bolt by the narrow sides of the elipse. The ear on the insert, assembled into a pre-drilled hole, prevents the nut itself from turning in service. The capnut may be adjusted and readjusted, and may be removed and reapplied over again without losing the locking power and without injury to the threads of the bolt.

Security Locknut Corp., Melrose Pk., Ill.

CONTINUED ON PAGE 222

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MADISON . . . A CITY

KIPP . . . A TRADE NAME AND TRADE MARK

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- *Skilled in* DIE CASTING *Mechanics*
- *Experienced in* LUBRICATION *Engineering*
- *Originators of Really High Speed* AIR TOOLS

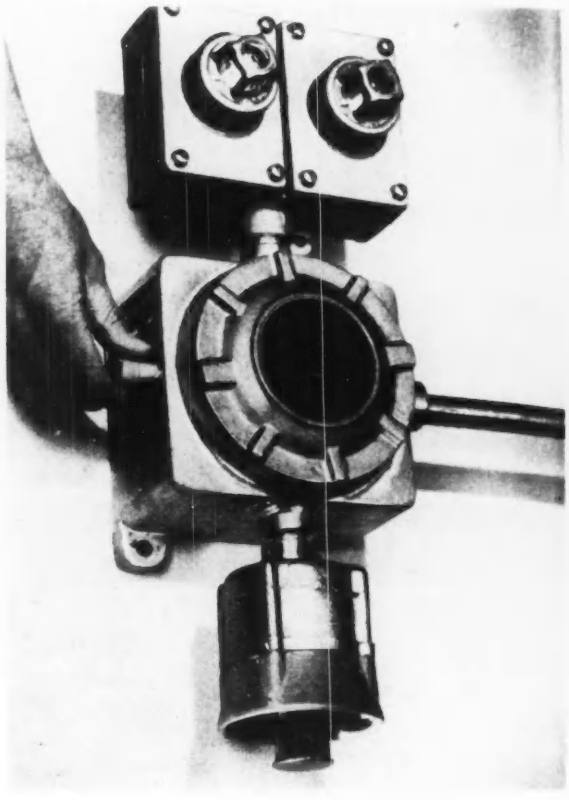
Explosion-Proof Combustible Gas Alarm

Because of its completely explosion-proof construction, this new model EE combustible gas alarm can be installed directly in the suspected atmosphere, either indoors or out. Located in a bell-shaped cover housing (at bottom in the illustration), the sensing unit is weather-proof like all parts of the unit. By convection and diffusion, the surrounding atmosphere is subjected to a continuous watch against the build-up of any kind of explosive vapors.

Presence of such vapor is signalled by a bright red indicator light as well as by remote alarm units of various types which can be connected to the terminals provided. While the standard alarm point is established at 0.2 of the lower explosive limit, other values can be used where required. Either self-reset or lock-in arrangements can be arranged to give a choice between an on-off indication of gas, or one which must be manually reset. The sensing unit can be located remotely from the rest of the alarm if desired.

Completely a-c operated, the model EE alarm is designed for rough-service locations. It contains no meters or meter-type sensitive relays, but uses an electronic trigger-tube circuit to convert the sensing-unit signals into alarm indications. The electronic chassis is arranged for quick and easy removal so it can be replaced with a spare chassis and conveniently shop serviced. The single-knob control combines a turn-to-balance and a press-to-test function. Stand-by power consumption from the 115 v line is 15 watts.

Features of the model EE make it applicable to pipe-line pumping stations, liquefied-petroleum gas plants, and industrial and commercial areas where gas or volatile liquids are used, stored or handled. The manufacturers say that unattended stations are particularly indicated.



Johnson-Williams Ltd., 2632 Third St., Palo Alto, Calif.

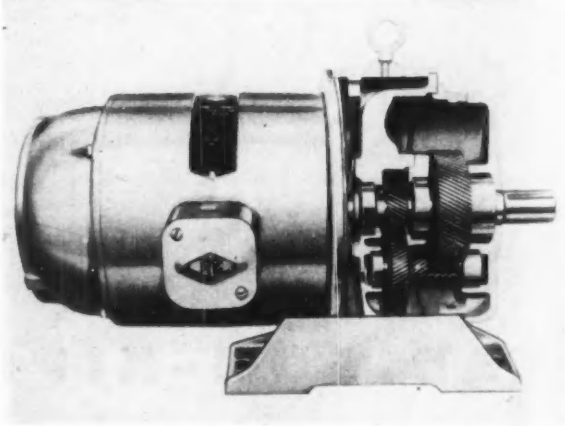
New Gear Reducer With Internal Fluid Coupling

This new unit consists of a standard fluid-shaft motor, and a gear train, designed into a single, compact unit. Its purpose is to convert the motor's conventional high-speed into a slow-speed, high torque output. The integral fluid coupling provides cushioned starting of heavy loads and protection against jamming of equipment. Possible applications are cranes, conveyors, dryers, mixers, car pullers and other machinery where heavy loads require smooth acceleration at reduced motor speeds.

One of the features of the motor reducer is its short lever arm length giving minimum torsional stress. The power-take-off shaft, gears and bearings are located immediately adjacent to the vertical centerline of the strong pyramidal base. Load pull is therefore transmitted direct to the base, minimizing any lateral stress. Gear and bearing wear are reduced. Mounting in close quarters is made easier.

The helical gears used are hobbed from special alloy steels, which have proved smoother, stronger, and quieter than previous types used. To assure good lubrication, all gears operate in an oil bath.

Standard motor reducers are available with squirrel-cage, fluid-shaft or slip-ring driving motor, either polyphase or single phase. Gear train can be either single or double reduction. All are available in either drip-proof or totally enclosed designs. Output speeds from 1 to 600 rpm, and wide range of ratings.



Reuland Electric Co., Alhambra, Calif.

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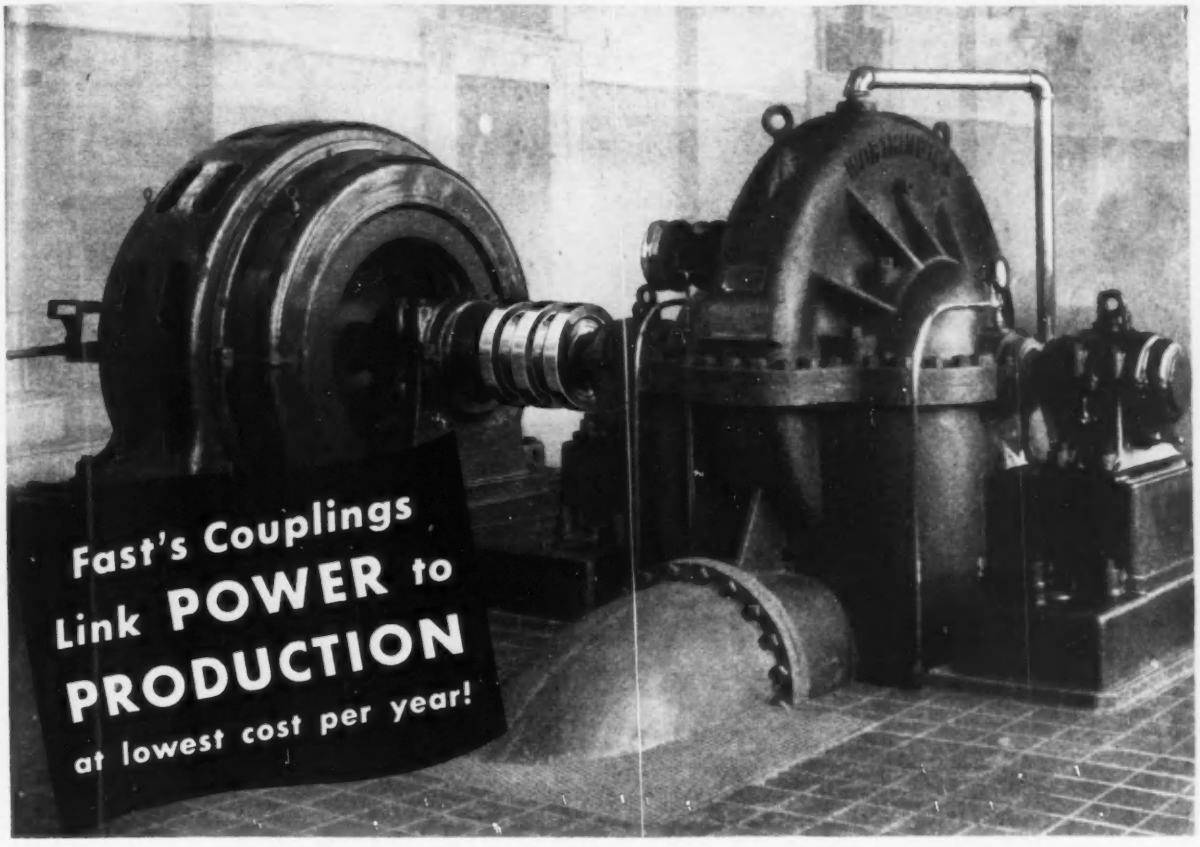

FAST'S Couplings usually outlast the equipment they connect!

ACTUAL cases on record show many Fast's Couplings are still in service after as much as 30 years of continuous operation! Time and time again, equipment has been replaced while the original Fast's Coupling remained on the job.

To you, these records of dependable, trouble-free service mean freedom from costly coupling failures when you specify Fast's. And they mean Fast's cost you far less to own and operate . . . because their cost can be amortized over long years of dependable performance.

For full details on how Fast's Couplings and Koppers Engineering Service can help you, write today for a free copy of our catalog to: KOPPERS COMPANY, INC., *Fast's Coupling Dept.*, 233 Scott St., Baltimore 3, Maryland.

Here's How FAST'S Save You Money

Free Service—Koppers free engineering service assures you the right coupling for the job.

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THE ORIGINAL
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INDUSTRY'S STANDARD FOR 32 YEARS

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233 Scott St., Baltimore 3, Md.

Gentlemen: Send me Fast's Catalog which gives detailed descriptions, engineering drawings, capacity tables and photographs.

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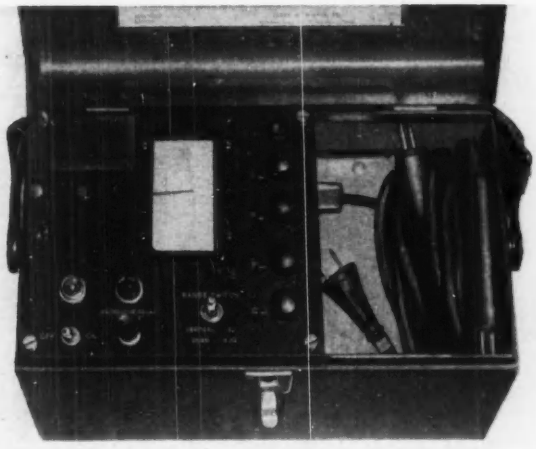
Wide Range Low Resistance Ohmmeter

This most recent addition to a group of electrical resistance measuring instruments was designed for maximum convenience in field use. The set is completely self contained with a compartment for storing leads and hand spikes. It is supplied in two models, both having the same ranges of 0 to 1,000 and 0 to 10,000 microhms.

Model 1B is a battery-powered set which employs two 4 FH dry cells, or equivalent. Model 1R shown in the illustration has a built-in rectifier which can be plugged into any ordinary lighting circuit outlet.

The ranges of the instrument cover a variety of applications, such as routine tests on circuit-breaker contacts, relays switches, bonds, connections and joints, and bar-to-bar tests on commutator type armatures.

The instrument has a quick acting automatic circuit-breaker in the current circuit of the instrument which is actuated by a trip coil whenever the potential across the resistance being measured is excessive.



James G. Biddle Co., 1316 Arch St., Philadelphia 7, Pa.

Portable Pump is Self-Priming At All Speeds

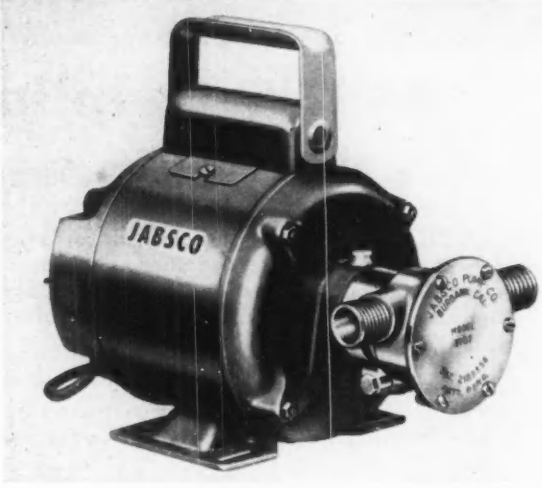
This portable pump and motor unit is self-priming at all speeds, and will start almost instantly even with dry suction lifts approaching 15 feet.

The pump uses a direct drive 1725 rpm, ¼ hp capacitor type motor, operating on 115 v a-c. Standard external garden hose connections of ¾ in. are used, with an optional ½ in I.D. pipe size available. Body material is bronze.

The standard impeller material is a neoprene compound, resistant to oils in varying degree. Some oils can be pumped easily; others cause trouble because they are absorbed by the impeller, causing it to swell.

As the impeller rotates, it carries the liquid through the pump, each successive blade drawing in the liquid. When the flexible blades contact the offset plate, they bend with a squeezing action, which provides a continuous discharge of liquid. Upon leaving the offset plate, the impeller blade straightens and creates a vacuum, drawing in the liquid.

For intermittent operation, pressures up to 30 lb are permissible. For continuous operation, pressures should not exceed 20 lb with standard impeller. At a total head of 4.3 psi, the pump has a capacity of 10 gpm. At a head of 21.6 psi, the output is 4.2 gpm. Operation at temperatures between 0 and 160 F will minimize impeller wear.



Jabasco Pump Co., 2031 N. Lincoln St., Burbank, Calif.

Compact, Line Voltage Type A-C Magnetic Starters

New, compactly designed, line-voltage type a-c magnetic starters in sizes 0 to 1, have contact carrier and stationary contact blocks of molded, high arc resistant melamine. All parts are easily accessible from the front. The contact assemblies may be replaced without disassembling the starter.

Ilsco solderless terminals, suitable for #6 wire, are standard; screw terminals are available on special order. The overload relay features palladium-silver snap action contacts. The enclosed heater element, with expanding U-shaped bimetal and snap action contact mechanism, gives accurate motor overload protection. Trip-free manual reset is standard, but manual automatic reset is available on special order.

On size 0 and 1 starters, all parts, except stationary and movable contact assemblies, are interchangeable. The overload relays may be mounted separately if desired.

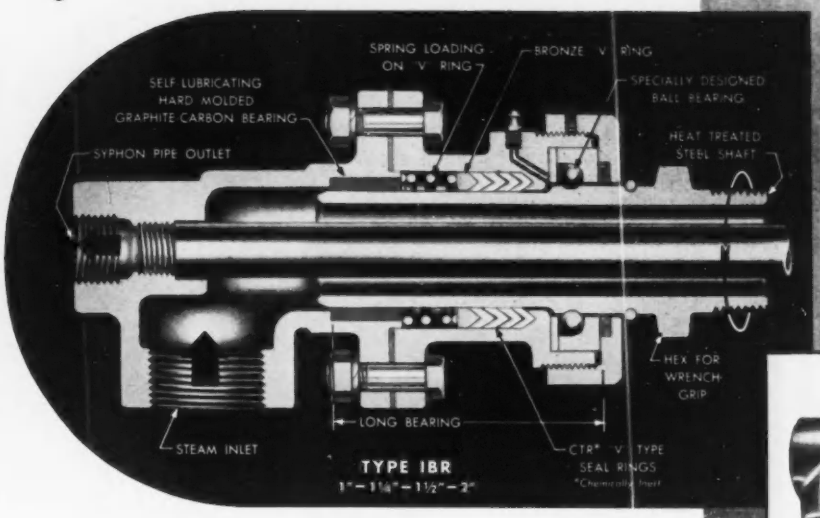
R-B-M Div., Essex Wire Corp., Logansport, Ind.

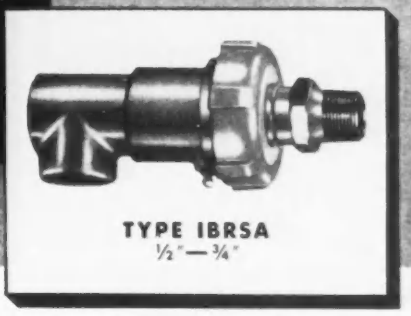
CONTINUED ON PAGE 224

Up to 50% power savings!

THE IMPROVED

BARCO REVOLVING JOINT





TYPE IBRSA
½"—¾"

FOR HANDLING STEAM, WATER, AIR, OIL, GAS

PRODUCT DESIGNERS throughout the country have been quick to recognize the ADVANTAGES offered by Barco's new *improved* Type IBR Revolving Joint for service on drum type dryers, coating rolls, calenders, mixing drums, chill rolls, sanforizers, and other rotating machinery:

- Free-Floating, Low Torque Installations.
- Up to 50% Power Savings.
- Better Temperature Control where steam is used for heating rolls.
- Low Maintenance; No Adjusting.
- Ability to Withstand Vibration and Hard Usage.
- All Parts Easily Accessible.

Barco builds a complete line of revolving joints in sizes ranging from ¼" to 5" in special models. Pressures to 250 psi, steam, or 1000 psi, hydraulic. Speeds to 2500 rpm. *Barco Engineers are at your service; ask for recommendations.* BARCO MANUFACTURING CO., 1827D Winnemac Avenue, Chicago 40, Illinois. In Canada: The Holden Co., Ltd.

Syphon Style—TYPE IBR. Built for 450°F., steam service to 150 psi, and up to 500 RPM. Hydraulic service to 200 psi, 750 RPM. Higher pressure and speeds under certain conditions.

Single Flow Style—TYPE IBRSA. Similar to Type IBR. Sizes 1" and larger have 2-piece flange connected body. Send for Bulletin 300.

BARCO

THE ONLY TRULY COMPLETE LINE OF FLEXIBLE BALL, SWIVEL, SWING AND REVOLVING JOINTS

WORLDWIDE SALES AND SERVICE

FREE ENTERPRISE—THE CORNERSTONE OF AMERICAN PROSPERITY

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Impulse Counter Has Own Power Supply

A new step-motor impulse counter to provide 100 percent accuracy up to 60 counts per second, has been designed to cover counting ranges above those possible with electromechanical counters and below those in which scalers are normally required. The device has a counting range which will make it useful in high-speed production counting. According to the manufacturers, it has been used in such applications as counting flaws in fabric at process speed. The counter may also be used in certain types of radiation counting where the use of a direct reading register is desirable.

The step-motor impulse counter consists of a step motor with a resetting type register, and a power supply enclosed in a steel case. The step motor and register assembly are mounted on the power supply enclosure, which contains an electronic switch and a high voltage supply capable of supplying the power requirements of a photo tube preamplifier.

The counting assembly on the newly designed device can be easily removed and placed in a remote position such as a control panel.

This impulse counter is rated at 0-60 counts per second, but the two-phase step motor is said to have high accuracy at continuous counting rates in excess of 100 counts per second, or for random counting.

Overall dimensions of the counter are 13 x 11 x 7 in. It weighs about 12 lb and operates on 115 v, 60 cycles.

General Electric Co., Schenectady 5, N. Y.

Automatic Shut Off Valve for Hydraulic Systems

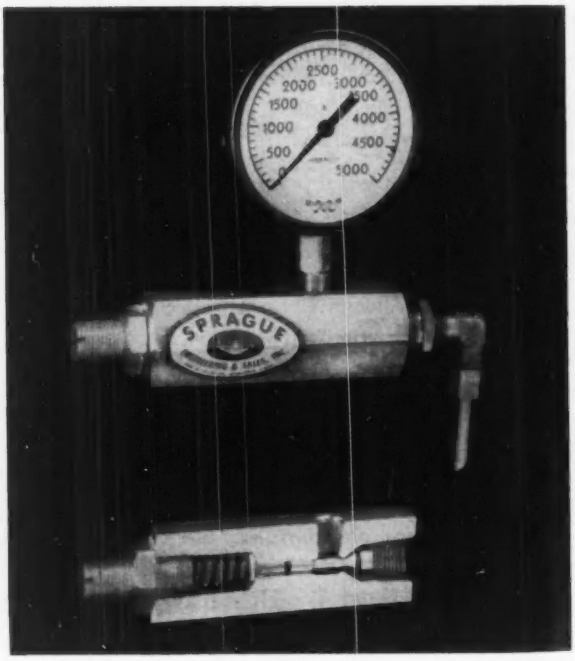
A new shut off valve, designed especially to protect gages in both pneumatic and hydraulic systems shuts off automatically and cuts out gages from the system when pressure goes beyond their operating limits. It automatically opens the gage to the system when the pressure is again within operating range of the gage.

The shut off valve is available for low pressure —30, 60, 100, 200 and 300 psi, and high pressure—500, 1,000, 1,500, 2,000, 2,500, and 3,000 and 5,000 psi.

Positive opening and closing action of the gage shut off eliminates the need for a relief valve and a manually operated gage shut off valve. When installed in a hydraulic system with multiple gages of various ranges, the shut offs are said to save valuable man hours spent in manipulating manual controls.

A compression spring controls the pressure shut off point. Minor changes or adjustments may be made by adjusting the screw positioned at one end of the shut off. Major changes of pressure shut off point are possible by replacing the compression spring. The heavier the spring, the higher the shut off point. All units are supplied with standard pipe thread connections but can also be furnished with AN adapters for aircraft fittings. The connection to the system is made at the end of shut off, $\frac{1}{2}$ in. pipe thread. Connection to the gage is made on the side of shut off $\frac{1}{4}$ in. pipe thread.

The overall length of the shut off valve is $5\frac{1}{2}$ inches, plus or minus $\frac{1}{2}$ inch. Distance across flats of hex shape body is $1\frac{1}{2}$ inches. Two O-rings are used on the sliding piston, shown below the gage fitting in the lower view.



Sprague Engineering & Sales Corp., 1144 W. 135 St. Gardena, Calif.

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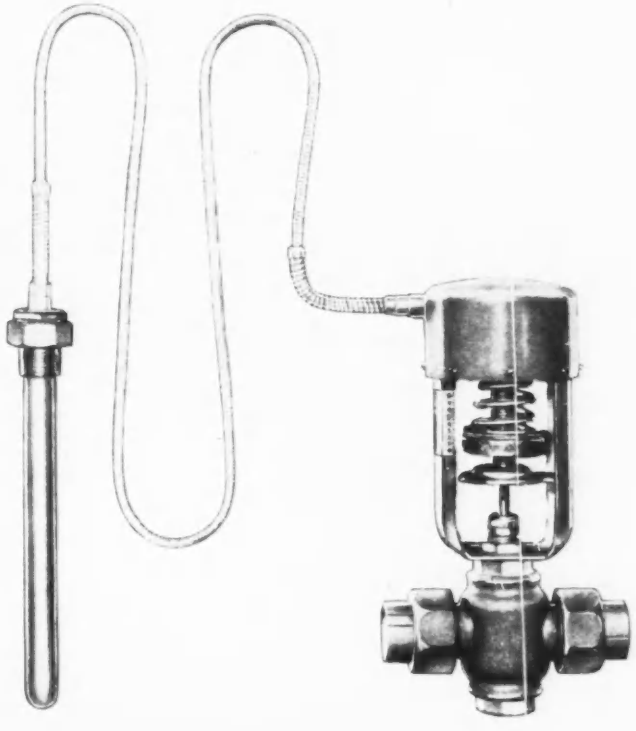
SYLPHON CONTROLS FOR DEPENDABILITY

SYLPHON CONTROLS FOR DEPENDABILITY

THIS "HAND" IS ALWAYS DEPENDABLE!



Make it "Standard" for your equipment... assure accurate temperature control

● Automatic Sylphon Controls, installed as standard equipment, do a better job, any time, than hand-operated valves or "guess methods" do at governing temperatures. They assure your equipments' best performance . . . save trouble for you and your customers . . . give you an extra sales advantage.

See why! Hour after hour, they maintain temperature that assures *uniform* processing conditions . . . *constant* product quality. They help reduce spoilage, wasteful overheating . . . save manpower and manhours.

Sylphon Temperature Regulator No. 999, pictured here, is one of the Sylphon line. Its outstanding features include stainless steel frame for minimum heat conduction from valve to regulator head . . . large size 2-ply Sylphon bellows for added power . . . less height and weight than other types. Self-operating—requires no auxiliary power source. Particularly suited for storage water heaters, metal plating tanks, bottle washers, treaters, slashers, etc.

Find out about the advantages of No. 999, or of other Sylphon Temperature Regulators, as standard equipment to help *your* machines operate better, longer, more economically. Write for Catalog EP-A.

FIRST WITH BELLOWS

Temperature Controls • Bellows Devices • Bellows Assemblies

FULTON SYLPHON
DIVISION

ROBERTSHAW-FULTON CONTROLS CO., KNOXVILLE 4, TENN.

Canadian Representatives: Darling Brothers, Montreal

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Heavy Duty, Portable Hydraulic Power Unit

A new heavy duty, portable oil hydraulic power unit with pressures to 5,000 psi, has been designed to provide hydraulic power for testing equipment, modernizing older machinery and for emergency power. This unit may be easily towed and can be used anywhere electrical power is available. The manufacturers claim that it is suited to the testing of aviation and automotive equipment, and the powering of machine tools and processing machinery.

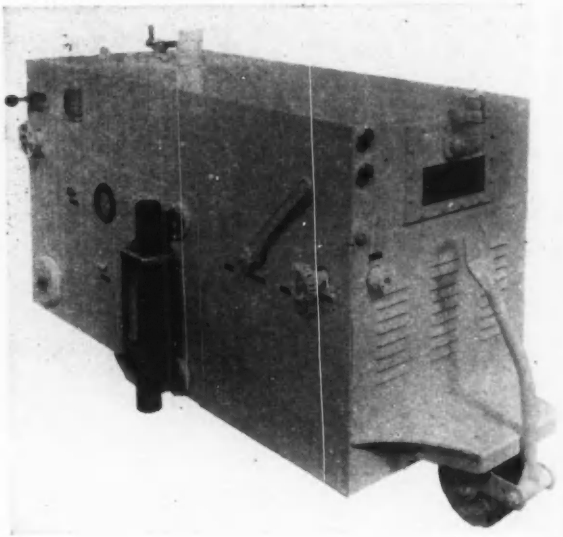
These units are built with fixed volume pumps in a wide range of sizes up to 60 gpm at 2,000 psi; hand-wheel and pressure compensated controls enable users to meet specific job needs up to 5,000 psi and 75 hp.

Multiple valve combinations and simple hand control of two pressure lines permit the pump to take suction from built-in 100 gal tank or from an outside source.

The unit has a micronic filter, built-in relief valve, flowmeter, pressure gages and electric controls, all mounted in a welded steel frame to JIC specifications.

The unit shown is 75 hp, developing 32 gpm at 3,000 psi. Overall dimensions are: 7 ft. 5 in. long, 3 ft. 9 in. high. Weight is approximately 3,750 pounds.

The Rucker Co., 4228 Hollis St., Oakland 8, Calif.



Worm Reduction Gears Are Fan Cooled

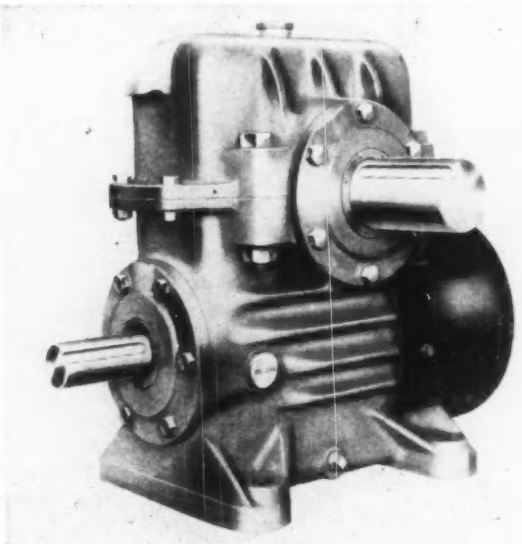
Radiation type speed reducers, a new line of worm reduction gears, offers a variety of ratios, with units ranging from 5 to 1 through 100 to 1, and from fractional up to 400 hp.

The smaller units, $1\frac{1}{8}$ in., $1\frac{3}{4}$ in., and $2\frac{1}{4}$ in. dia., feature universal mounting for worm on bottom, top, or vertical installation. While delivery is made with assembly as specified, legs are removable and can be mated to other holes in housing to permit varied mounting.

The case has a large surface area with vertical and horizontal ribbing to allow for maximum heat radiation. A fan fitted to the worm shaft directs a stream of cool air along the exterior ribs on the gear case. There are ten sizes ranging from $3\frac{1}{2}$ in. through 14 in. that are all fan cooled.

Dual purpose ball bearings are used on both the worm and wheel shafts to allow for radial and thrust loads, with a roller bearing in addition on the wheel shaft. All joints on the case are machined and made oil tight, and dust proof. Oil seals are fitted to the high speed worm shaft.

National Transmission Distributors Inc., 684 Broadway, New York 12, N. Y.



A FLEXIBLE SPIGOT AND SOCKET JOINT which does not separate or disjoin under high working pressures can be used by gas and water supply plants and industries in cases where there is danger of the separation of a spigot and socket joint resulting from high pipeline pressures. No straps and ties, which are difficult to protect from corrosion, are used. Instead of these a steel ring, a shallow-groove in the spigot end of one of the pipes of the joint, and a bevelled edge of a cast-iron pressing ring prevent the joint's separation. Flexibility remains intact. The spigot and socket joint is warranted for working, as high as 294 lb psi, for a 0.4 in. pipe, down to 117 lb for a 1.1 in. pipe. Royal Netherlands Blast Furnaces & Steel Wks., Muiden, Netherlands.

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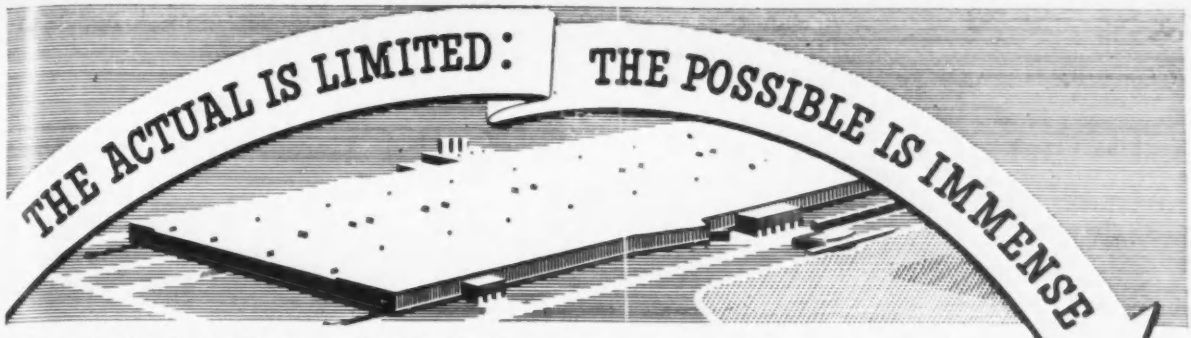

NEW LINCOLN PLANT CREATED BY INCENTIVE-INSPIRED CO-ACTION IN DEVELOPING POSSIBILITIES IN PRODUCT

© LE Co. 1952

PROPER DESIGN IN WELDED STEEL IMPROVES PRODUCT . . . cuts costs for Hanson-Van Winkle-Munning

THE examples show how one prominent manufacturer has improved the quality of his products while cutting costs by converting to welded steel design.

When designing for efficient welded steel construction, savings in initial material cost alone generally average 85% to 95%. This is because steel costs less per pound. And with steel's greater strength and rigidity, fewer pounds of metal are needed. In many cases, machining operations required for iron can be minimized or eliminated entirely.

Where product designs utilize the economies of welded steel, cost analyses show that:

1. Material costs for steel generally range from 5% to 15% as compared with castings.

2. Labor costs for fabricating steel are about 30% of initial casting purchase costs.

3. Welding costs average 50% of total labor costs for fabricating steel.

If your costs do not approximate these averages, your product designs should be reappraised. A Lincoln Welding Engineer will gladly point out what benefits of welded steel may have been overlooked.

Inquire about the "Weldesign Training Course" for your engineers, designers and production men.

Fig. 3. Welded steel *saves 30% cost . . . cuts weight 50%. Design is simpler . . . plain channel replaces complicated casting.*

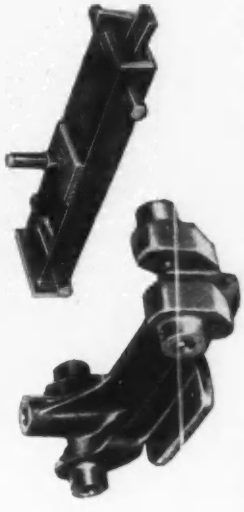

Fig. 4. Stronger, more rugged machine part *results when fabricated from steel strip and standard channel. Weight is cut from 3 lbs. to 2 lbs. 4 oz. Cost of this small part is 12% less.*

ORIGINAL CONSTRUCTION

Fig. 1. Machine bracket *for* **Hanson-Van Winkle-Munning,** *Matawan, N.J. weighed 50% more than present steel design. Casting had to be left heavy for strength in hub and arm. Design made efficient use of cast iron by providing cored slots. Casting required milling and drilling.*

PRESENT WELDED STEEL DESIGN

Fig. 2. Finished weldment *costs 25% less . . . eliminates former breakage experienced in casting. Steel hub, cut from bar stock and pre-drilled, is welded to simple formed steel arm in which holes are pre-punched.*

MORE SAVINGS

Machine Design Sheets are available to designers and engineers. Write on your letterhead to Dept. 33,

THE LINCOLN ELECTRIC COMPANY

CLEVELAND 17, OHIO

The World's Largest Manufacturer of Arc Welding Equipment.

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High Capacity, Portable Load Cell Calibrating Unit

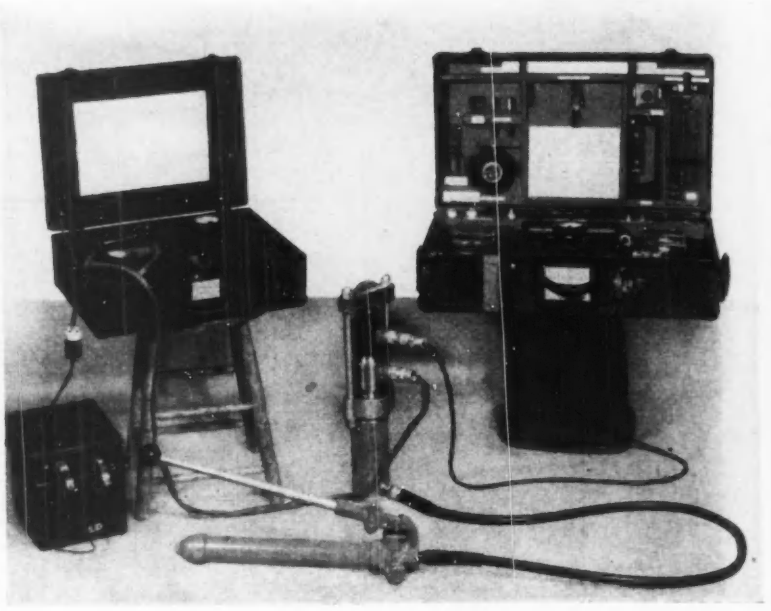
To meet the demand for strain gage load cell calibrating equipment, the new EC-1 portable unit illustrated has been developed for compression loads. Most load cells now used measure thrust, torque, and weight.

The EC-1 unit is available in capacities of 10,000 lb, 25,000, 50,000 and 100,000 pounds. Accuracy is guaranteed to 1/20th of 1 percent of the applied load. It is adaptable to load cell testing in any weight range.

The illustration shows a load cell on a standard electronic weighing kit being tested. The case on the left contains the EC-1 amplifier and load cell. The two cases weigh only 50 lb, and are easily transportable.

The load cell to be calibrated or checked is placed in series with the accurate master cell in the ram frame assembly. Load is applied to the ram by the hand pump which will hold a pressure until readings are taken.

Cox & Stevens Aircraft Corp., Mineola, N. Y.

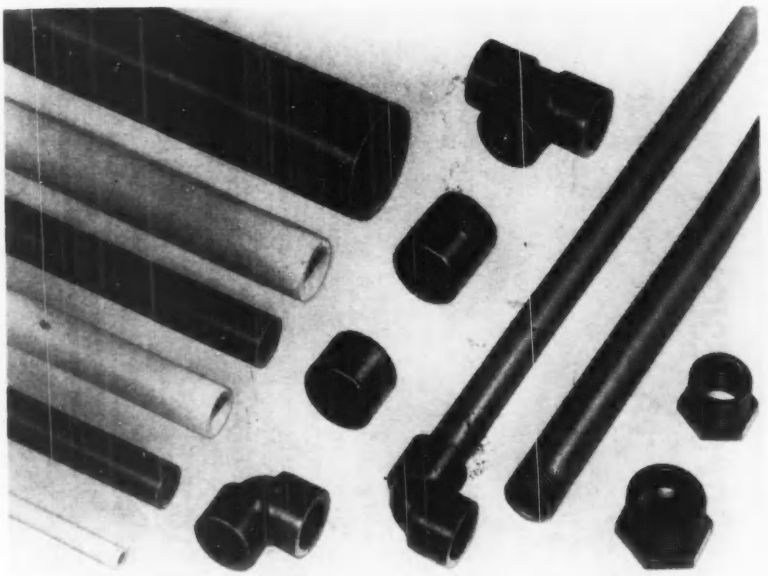


Non-Plasticized Polyvinyl Chloride Extruded Pipe

Polydur 162, is said to be the first non-plasticized polyvinyl chloride pipe produced in this country by continuous extrusion methods. This non-plasticized PVC resists all types of chemical attack, and has been fabricated into process tanks, tower sections, ducts, filters, and valves, when first produced in Germany. Made in this country, it is compounded entirely from domestically produced ingredients.

Polydur 162 is a rigid, high molecular weight pipe that is both hard and tough at the same time. It is extruded in extra heavy wall pipe up to and including 2 inches. At temperatures below 170 F it is capable of conducting acids, alkalies, salts, oxidizing agents, oils, greases, alcohols, gasoline, carbon tetrachloride, and others. It can be machined, welded, threaded and formed by heating it above 250 F. Plain end or flange pipe are furnished in lengths of 10 or 25 feet.

Polydur's impact strength remains high at sub-zero temperatures. It will not become brittle. Neither will it deteriorate with age. Its water absorption rate is low; it is completely self-extinguishing; and, it is a good dielectric. Where its temperature limits permit, polydur can replace heavy metal pipe, and expensive alloys.



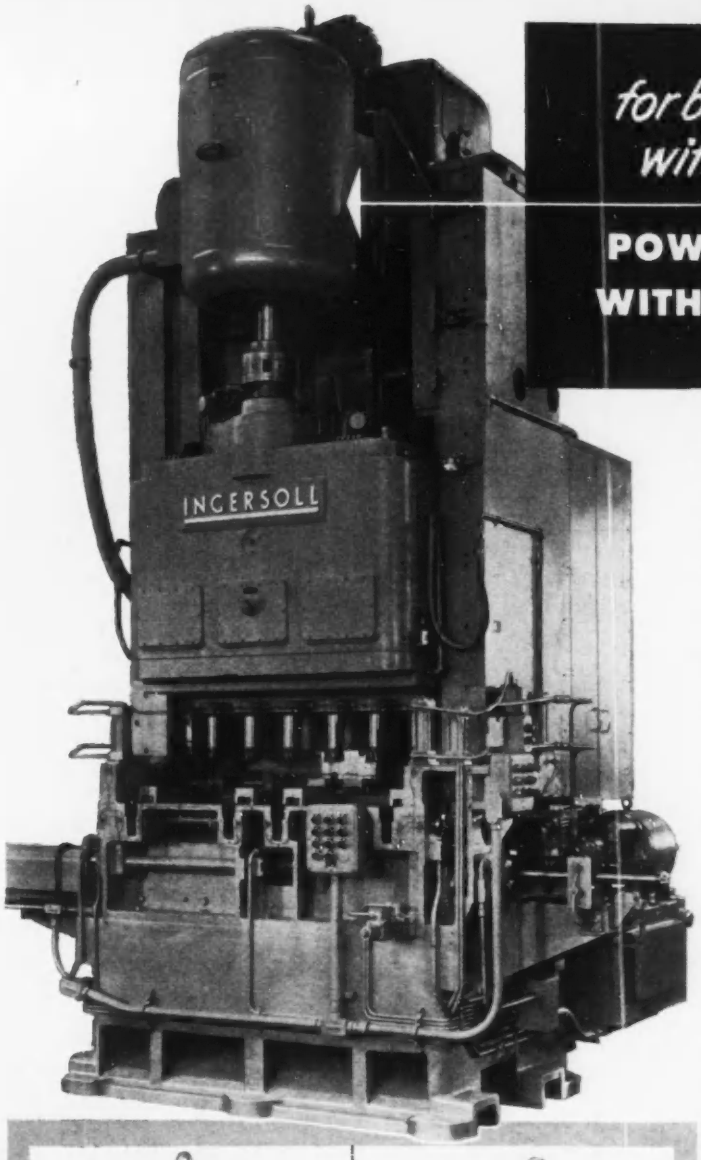
Some of the physical properties are: tensile strength, 5500-6050 psi; Rockwell hardness, 106-107; specific gravity, 1.56; heat distortion, 176 F, R. T. Impact ft-lb/in. notch, 0.75.

Munray Products, Inc., 12400 Crossburn Ave., Cleveland 11, Ohio

CONTINUED ON PAGE 230

for better performance with less down-time

POWER YOUR PRODUCT WITH Wagner MOTORS



Modern high-speed production is based on the ability of machine tools to turn out a continuous flow of identical parts. Precision is all-important—so is continuity of operation. Machine tools powered with Wagner totally-enclosed Motors are assured freedom from excessive down-time caused by motor failure, because these motors are designed to operate under the adverse conditions often encountered in machine tool operation. They are fully protected against steel-filings, chips, dust, dirt, fumes and moisture. They require no maintenance other than periodic lubrication.

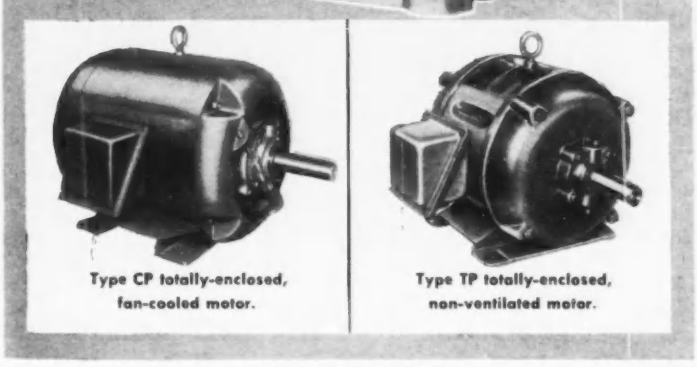
The machine pictured here does rough boring of 6-cylinder engine blocks. It is equipped with Wagner totally-enclosed fan-cooled motors. At the top is a 100 hp Wagner Type CP.

When you power your equipment with Wagner Motors, you assure users uniform performance with exceptionally little trouble, and you give your product an added selling point that's hard to beat.

* * *

When you standardize on Wagner Motors —you get the advantages of a liberal warranty . . . of nationwide service facilities, with replacement motors and parts available from more than 650 Authorized Service Stations plus 25 Wagner-owned Service Branches.

You can choose from a wide variety of types and sizes (from 1/125 to 400 hp). Bulletin MU-185 gives complete information—write for your copy.



Type CP totally-enclosed, fan-cooled motor.

Type TP totally-enclosed, non-ventilated motor.

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ELECTRIC MOTORS • TRANSFORMERS • INDUSTRIAL BRAKES
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MU54

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Variable Speed Drives Have Automatic Control

Formerly only available with handwheel and electric remote controls, the series 1000 fractional horsepower vari-speed moto drives are now available with mechanical automatic control.

The series 1000 motodrives are manufactured in ¼, ⅓, ½, and ¾ hp sizes, with special variations as high as 10 to 1. These motodrives are compact, with each unit a complete variable speed power plant, consisting of the speed-varying mechanism made by this company, and the user's choice of any standard motor, with a built-in helical gear speed reducer optional. A total of 24 different assembly combinations are available for each horsepower rating.

The motodrive is one of three basic units designed by this company to meet variable speed control requirements. Other units are the variable speed transmission, in capacities up to 87 hp, and speed variation as high as 16 to 1; and the vari-speed motor pulley, available in capacities up to 10 hp and speed variations up to 4 to 1.

The fractional motodrives have complete units as small as 9⅜ in. in height and 16⅞ in. in length, and should find good use where space is limited.

Complete information on these and other units may be obtained by writing to the manufacturer.

Reeves Pulley Co., Columbus, Ind.

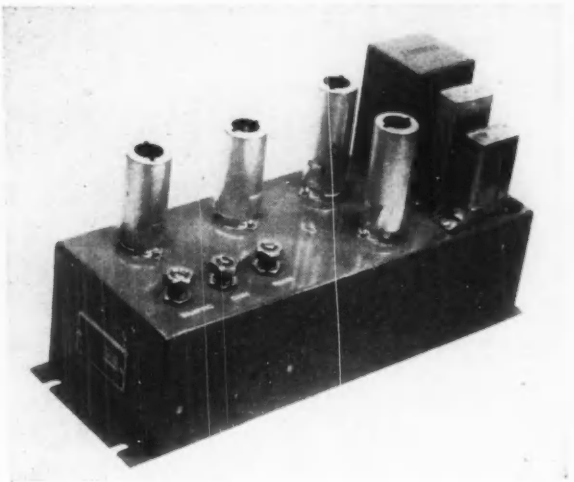
400 Cycle Servo Amplifiers For Two-Phase Motors

The models 421-A, and 423-A shown in the illustration are universal, 400 cycle servo amplifiers, designed to drive two-phase servo motors requiring 6 and 9 w per phase respectively. They feature independent, screwdriver controls on damping, gain and carrier phase, and can be stocked for use in all servo loops using their servo motors.

Other characteristics are: maximum gain, 1,000; phase adjustable thru 160 deg; internal pickup below 2 millivolts; damping adjustable over wide range. Their plate and filament power can be supplied by any power supply, with no regulation, filtering, or additional bias sources necessary. They will function with any carrier frequency data system, and yield servo loops of broad frequency transmission and low static and velocity errors.

These amplifiers, together with 60 cycle, model 410-B, also designed by this company advance the theory of "breadboard circuitry." The range and applications of the amplifiers will eliminate engineering development.

Industrial Control Co., Wyandanch, L. I., N. Y.

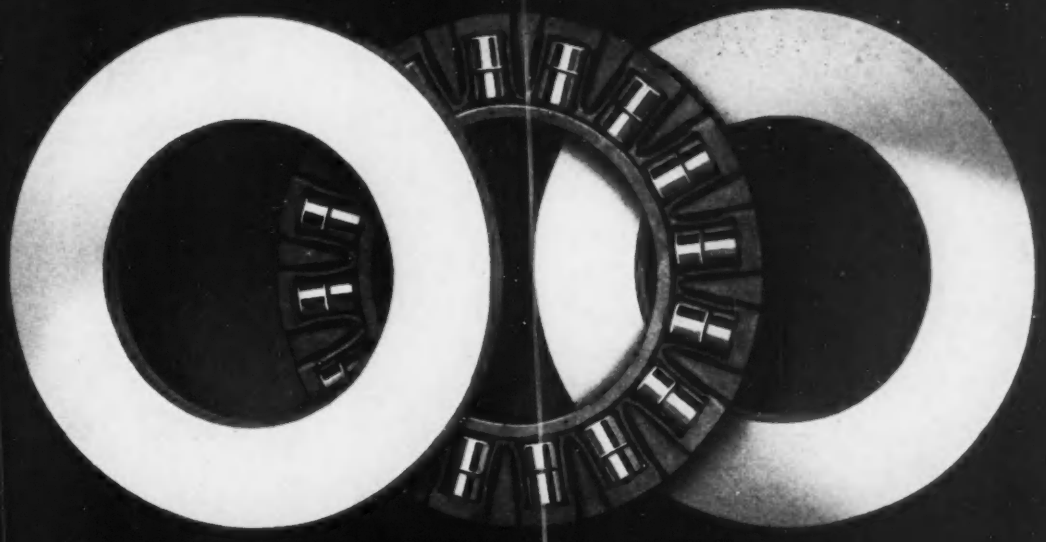


A NEW ZINC CHROMATE COMPOUND with a vinylite resin base called Vorac H-400 has been found to be effective as an anti-corrosion metal wash primer. The compound is used under many types of coatings, and requires no oxidation or polymerization. It is also a metal conditioner and applied only to clean surfaces. It will dry in less than 30 minutes. Bakelite Co., 122 E. 42 St., N. Y. 17, N. Y.

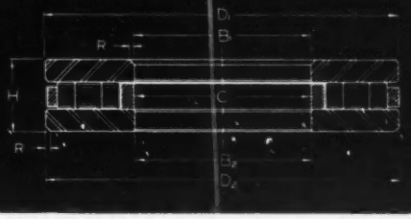
A MINIATURE, ADJUSTABLE, metal-enclosed thermostat, designed for long term stability and accuracy has a temperature range from —50 to 350 F and is adjustable ± 60 F from its original factory setting. Contacts rated at 1 amp, 115 v a-c, or 0.5 amp, 115 v d-c. A phosphor bronze spring holds the moving contact. Overall shell length is 1¾ in., and diameter about $\frac{5}{16}$ inch. Thomas A. Edison Inc., Instrument Div., W. Orange, N. J.

CONTINUED ON PAGE 232

KAYDON TYPE RT THRUST ROLLER BEARINGS



STRAIGHT ROLLER TYPE
FLAT RACES
TYPE RT



SIZES AS LISTED
CARRIED
IN STOCK

Bearing No.	Sizes and Dimensions • See Drawing Above						Roller Diam.	R 45° Chamfer	Lbs. †Capacity at 100 R.P.M.
	B_1	B_2	C	D_1	D_2	H			
RT-26	2.002"	2.015"	2.010"	5.968"	6.000"	1.375"	½"	.062"	36,000
RT-27	2.002	2.015	2.010	6.968	7.000	1.375	½	.062	48,300
RT-28	2.002	2.015	2.010	7.968	8.000	1.375	½	.062	65,400
RT-36	3.002	3.015	3.010	5.968	6.000	1.375	½	.062	29,800
RT-37	3.002	3.015	3.010	6.968	7.000	1.375	½	.062	43,600
RT-38	3.002	3.015	3.010	7.968	8.000	1.375	½	.062	55,600
RT-39	3.002	3.015	3.010	8.968	9.000	1.375	½	.062	67,500
RT-47	4.002	4.015	4.010	6.968	7.000	1.750	⅝	.062	34,700
RT-48	4.002	4.015	4.010	7.968	8.000	1.750	⅝	.062	54,600
RT-49	4.002	4.015	4.010	8.968	9.000	1.750	⅝	.062	69,400
RT-410	4.002	4.015	4.010	9.968	10.000	1.750	⅝	.062	89,300
RT-58	5.002	5.015	5.010	7.968	8.000	1.750	⅝	.062	40,300
RT-59	5.002	5.015	5.010	8.968	9.000	1.750	⅝	.062	63,300
RT-510	5.002	5.015	5.010	9.968	10.000	2.000	¾	.125	83,300
RT-511	5.002	5.015	5.010	10.968	11.000	2.000	¾	.125	111,600
RT-512	5.002	5.015	5.010	11.968	12.000	2.000	¾	.125	136,300
RT-69	6.002	6.015	6.010	8.968	9.000	2.000	¾	.125	48,300
RT-610	6.002	6.015	6.010	9.968	10.000	2.000	¾	.125	76,000
RT-611	6.002	6.015	6.010	10.968	11.000	2.000	¾	.125	100,100
RT-612	6.002	6.015	6.010	11.968	12.000	2.000	¾	.125	124,300
RT-710	7.002	7.015	7.010	9.968	10.000	2.000	¾	.125	62,400
RT-711	7.002	7.015	7.010	10.968	11.000	2.000	¾	.125	85,800
RT-712	7.002	7.015	7.010	11.968	12.000	2.000	¾	.125	109,200

ABOVE SIZES IN STOCK FOR IMMEDIATE SHIPMENT

KAYDON *Types of Standard or Special Bearings:*

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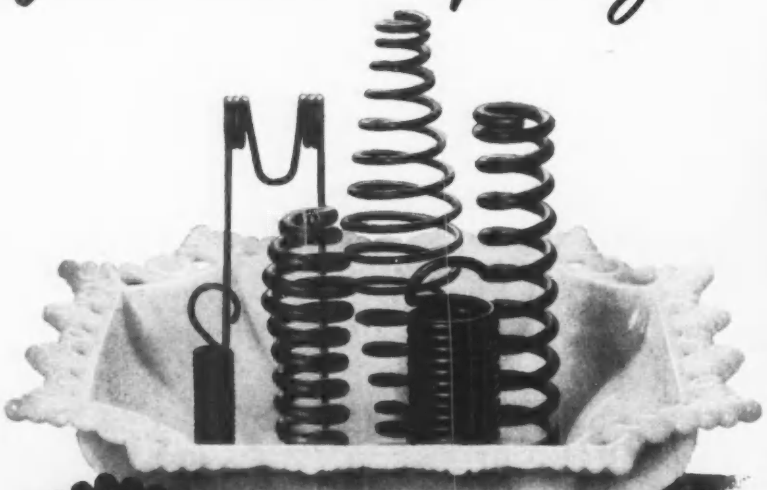


HOT OR COLD WOUND

PLACE thoroughly seasoned engineers in a modern plant.

ADD the finest spring-making equipment.

USING the latest metallurgical methods maintain the highest standards of quality.

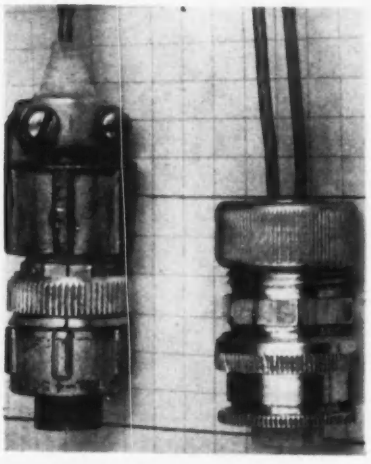
SERVE to customers precisely as specified.

AMERICAN-FORT PITT
SPRINGS

AMERICAN-FORT PITT SPRING DIVISION
H. K. Porter Company, Inc.
No. 2 John Street, McKees Rocks, Pa. (Pittsburgh District)

Wires Have Individual Packing Gland

This new electrical connector conforms to AN specifications but is lighter, shorter, and without clamps, eliminating the need for most right angle connectors. The new connector is weather-proof, waterproof, acid-



proof, and vibration resistant. Lead wires into the connector are provided with an individual packing gland, making them compression sealed against moisture, acid, fumes, and atmospheric changes. The shell can be mounted in desired fixed position before installing other wiring which may be bench assembled.

Salsbury Corp., 1161 *E. Florence Ave., Los Angeles, Calif.*

Limit Switch Is Completely Hermetically Sealed

A new-type limit switch that is completely hermetically-sealed is said to offer special advantages for uses even under the most adverse conditions. It has several industrial applications with special value in places where ordinary splash-proof or enclosed switches are not adequate because of humid or corrosive atmosphere, excessive dust and other difficult conditions. Because of the hermetic sealing (with inert atmosphere), this electro-snap switch is considered proof against freezing, corrosion, explosions, the accumulation of dust on contacts, and tampering.

Though light and compact, the hermetically-sealed electro-snap limit switch is of strong construction. It weighs 0.38 of a pound with overall dimensions of $2\frac{9}{16}$ in. x $1\frac{9}{16}$ in. x $1\frac{3}{16}$ inches. Actuator is capable of more than 100,000 electrical operations or 200,000 mechanical movements. The

internal switching mechanism is said to endure in excess of 10,000,000 mechanical cycles of operation.

An important feature of the switch is a tipping diaphragm action (no sliding parts) to prevent jamming from ice formation. A hardened steel pivot under diaphragm gives strong support. Other construction details include doublepole, double-throw switching with nearly simultaneous break. Single-pole, double-throw is optional. A new design 4 or 8 pin connector eliminates condensation around terminals. Rubber sealed outer connector is available for making connection to completely enclose outer materials. All components are bonded in an integral unit by copper-brazing. The cover is retained mechanically and sealed by induction soldering.

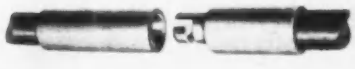
The manufacturers claim that there is no condensation within the enclosed mechanism from humidity and temperature cycling. Therefore, there is no danger of the switch components freezing. Performance is said to be equal at sea level or 50,000 ft.

The Exhibt Supply Co., 4218 W. Lake St., Chicago, Ill.

Interchangeable Welding Cable Connector

The design of the new cam-lok welding cable connector consists of a double cam principle where one cam exerts pressure parallel to the axis of the connector, the other perpendicular to the axis. The contact approaching the 600 psi needed for minimum resistance is obtained. The connector is made of solid brass machined to a smooth sliding fit.

General purpose connectors (for 1/0 through 3/0 cable and No. 2 through 1/0 whip ends) are com-



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THESE FACTORS COMBINE TO MAKE THE FINEST STEEL BALLS OBTAINABLE BECAUSE THEY CONTRIBUTE TO CLOSER SURFACE UNIFORMITY—BETTER STRAIN DISTRIBUTION—HIGHER LOAD CARRYING CAPACITY—LONGER LIFE
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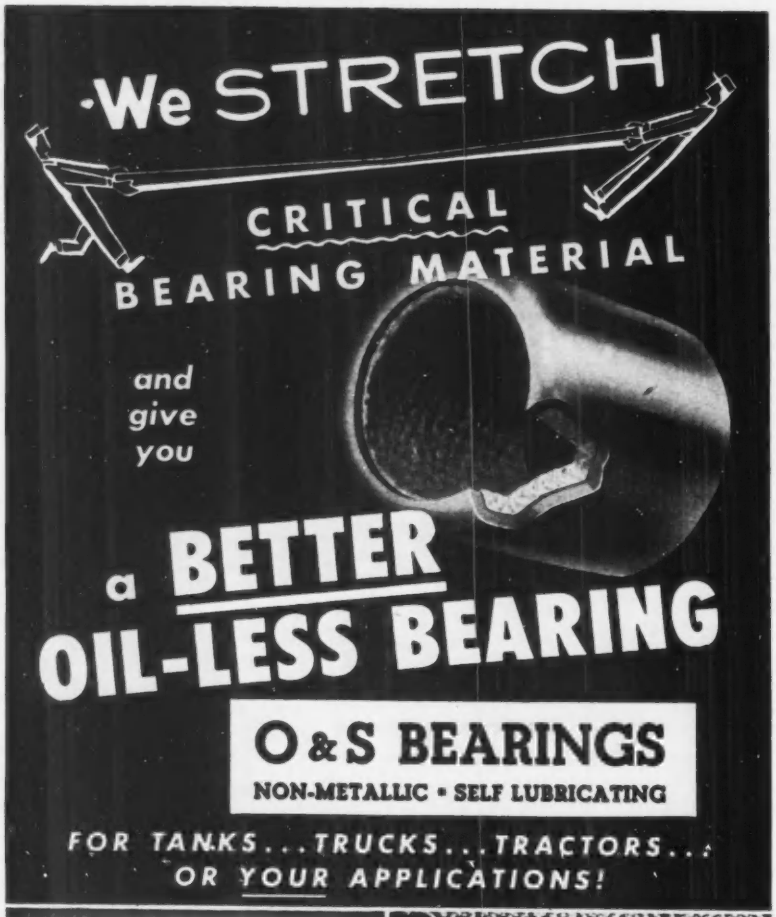

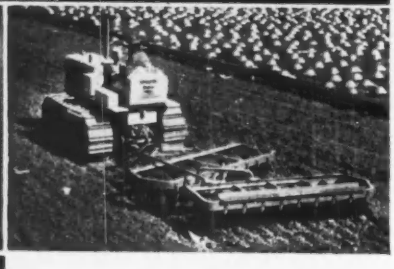

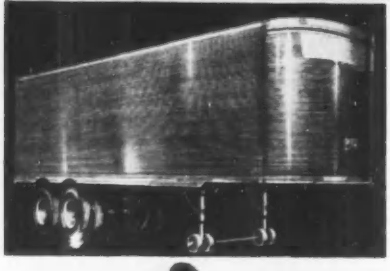

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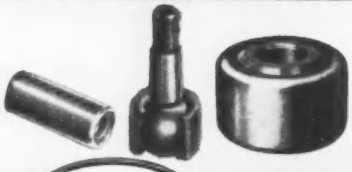

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NeverOil · SINCE 1910 ·

O & S BEARING CO.

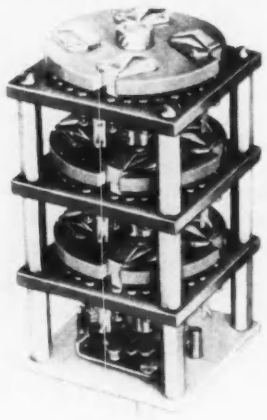
303 SOUTH LIVERNOIS · DETROIT 17, MICHIGAN

pletely interchangeable with the heavy duty connectors and with general purpose and heavy duty female terminal connectors. Long runs of cable can be graduated from 4/0 down to a light whip end for maximum flexibility and minimum voltage drop. No adaptors or reducers are needed. The connector is said to be self-compensating for wear, locks tight, releases easily, has no spring action, and reduces arcing and burning to a minimum.

Empire Products, Inc., Cinn., Ohio

Switches For High-Speed Work

Now constructed according to specifications JAN and MIL, all switches made feature silver allow contacts and slip rings, knee action rotor, positive roller type detent action which does not add to the depth of the unit, and switch stops which are independent of

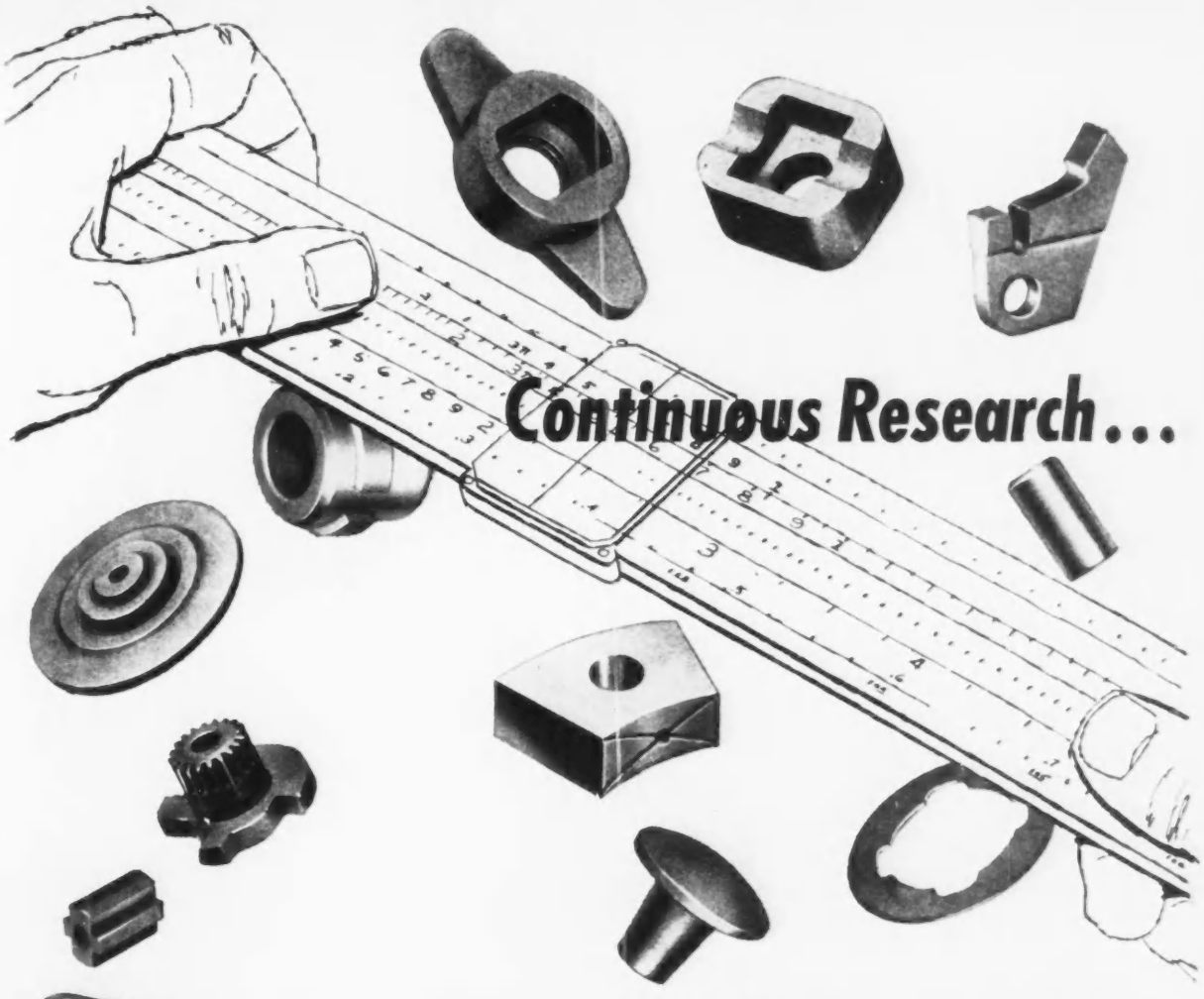


rotors. Occupying small space the switches are constructed for use over long periods of time. Available for high-speed work for such applications as telemetering, plus work, and other military applications.

The Daven Co., 191 Central Ave., Newark 4, N. J.

Ring Gaskets Has Two Independently Acting Seals

The design of the new Flex-Tip ring joint gasket incorporates two independently acting seals as compared to the one type offered in other gaskets. The first sealing mechanism is the standard API metal to metal seal acting exactly as in the standard gasket. Two additional features are the resilient flex-tip and the inner and outer beads which offer protection against mechanical damage to the smooth steel seating



Continuous Research...

Continuously Wider Benefits!

An important part of Moraine's operations is a continuous program of engineering research and production improvements.

This program, supported by Moraine's experience and knowledge, each year broadens the range of application of Moraine metal powder parts by making it practical to work to closer tolerances and to produce more complicated designs.

Moraine has demonstrated to many industries its ability to produce metal powder parts for them . . . faster and at lowered costs.

Metal Powder Parts by Moraine

MORAINE PRODUCTS DIVISION OF GENERAL MOTORS DAYTON, OHIO

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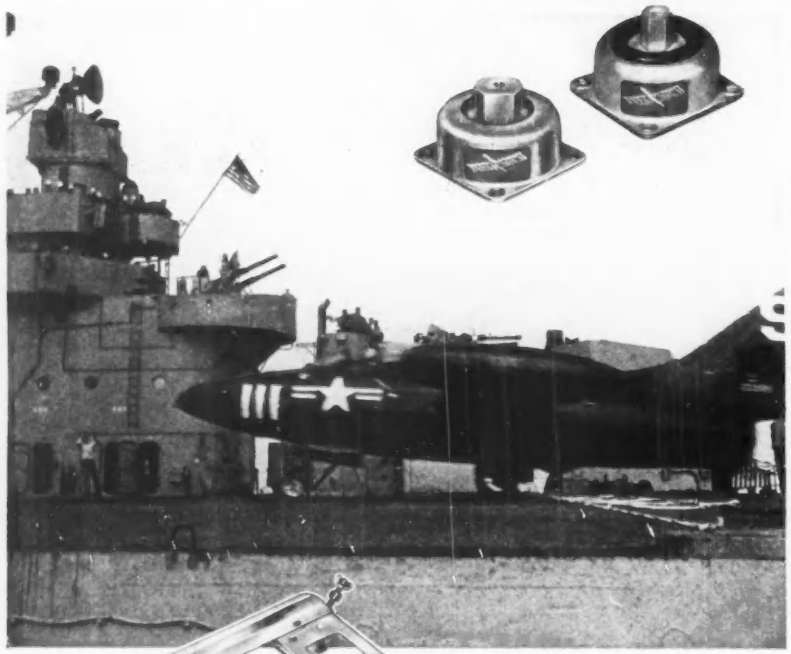
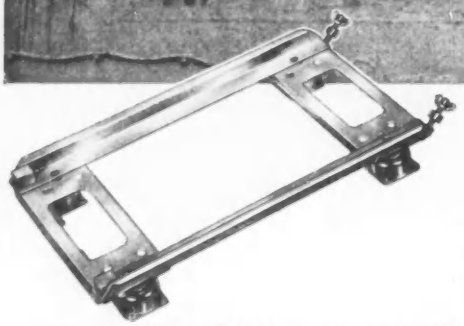
SHOCK and VIBRATION NEWS

BARRYMOUNTS FOR ASSURED CONTROL OF SHOCK AND VIBRATION

can YOUR equipment stand the shock of carrier landings? Barrymounts can!



Official United States Navy Photograph



New military specifications for all services require ruggedization of your equipments with their mountings.

Ruggedized Air-damped and All-Metl Barrymounts and mounting bases are now available to meet the shock test requirements of specifications MIL-T-5422 (Aer), MIL-E-5272 (USAF), and ANE-19. These mountings hold your equipment securely and maintain uniform performance characteristics even after the repeated shock of many aircraft carrier landings.

For full information about Barrymounts and bases, write today for your free copy of each of these Barry catalogs:

Catalog #524—Ruggedized Barrymounts and ruggedized mounting bases.

Catalog #523—Air-damped Barrymounts and mounting bases.

Catalog #509—All-Metl Barrymounts and mounting bases.

THE **BARRY** CORP.

730 PLEASANT ST., WATERTOWN 72, MASSACHUSETTS

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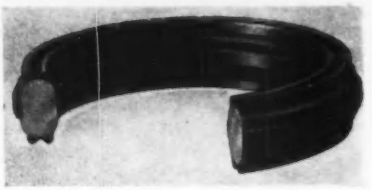
Atlanta, Chicago Cleveland Dallas Dayton Detroit Los Angeles Minneapolis New York Philadelphia Phoenix Rochester St. Louis San Francisco Seattle Toronto Washington



surfaces. The beads also protect the ring against corrosion, since the resilient material is little affected by oil, gas or commonly encountered chemicals.

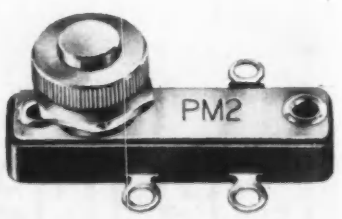
The flex-tip mechanism uses the interference principle of sealing similar to that of the common O-ring. A new compound has been added to give resistance to chemical reagents commonly found in connection with drilling for or producing petroleum.

The gaskets are manufactured in all sizes used in well control for pressures of 2,000 psi and above; for 600 and 900 series in sizes two to twelve inches; for series 1,500 in two to twelve inches; and for series 2,900 in sizes two to ten inches. The following features are obtainable: (1) The effectiveness of the second seal is independent of the initial tension of the bolting. With bolting made up slightly more than finger tight, test pressure can be held indefinitely without damage to flange, ring or bolting. (2) The combination of inert material with steel enclosure on all sides give a seal that is permanent. (3) The seal is not destroyed easily by foreign material trapped in a ring groove, or by poor surface finish. (4) Units can be stored indefinitely without deterioration. (5) The second seal does not lose sealing ability without repeat use.

Petroleum Mechanical Development Co., Houston, Tex.

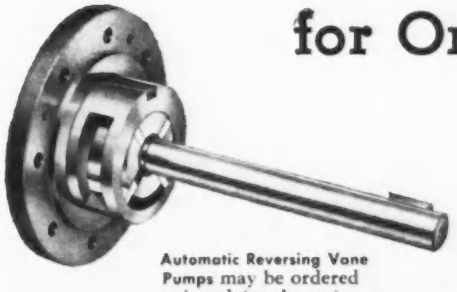
Miniature Panel Mount Switch

The new model PM Tyniswitch is a miniature panel mount type measuring $1\frac{5}{8}$ x $\frac{7}{16}$ $\frac{3}{4}$ in., and weighing approximately 17 grams. This switch gives precision snap action, long life and high rating. Its compact design makes it a good switching component



Complete Selection of PUMPS

for Original Equipment

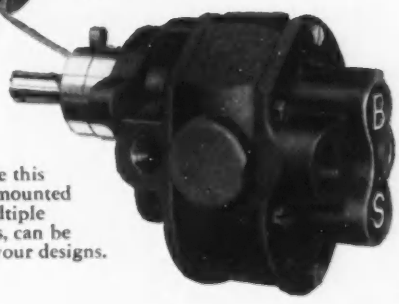


Automatic Reversing Vane Pumps may be ordered stripped (as shown) or semi-stripped, for "built-in" applications, or with housing and foot mounting.

Coolant, Lubrication, Hydraulic System, and Misc. Machine Pumps

Rotary Geared Pumps supplied with helical or herringbone gears for pumping oil under pressure, or with spur or helical gears for general purpose applications.

Centrifugal Pumps available for a wide variety of coolant and transfer applications.



Special Pumps like this compact flange-mounted type, having multiple pipe connections, can be furnished to fit your designs.

It's easy to select just the right Brown & Sharpe Pump for your job. You can choose from a wide variety of types and sizes . . . centrifugal, geared, reversing vane . . . direct or motor driven. All have the quality construction and long, trouble-free life characteristic of Brown & Sharpe products.

The complete specifications on each type and size are clearly presented to you in the Brown & Sharpe Pump Catalog. It includes illustrations, installation dimensions, and charts showing performance data. Write for your copy. Brown & Sharpe Mfg. Co., Providence 1, R. I., U.S.A.

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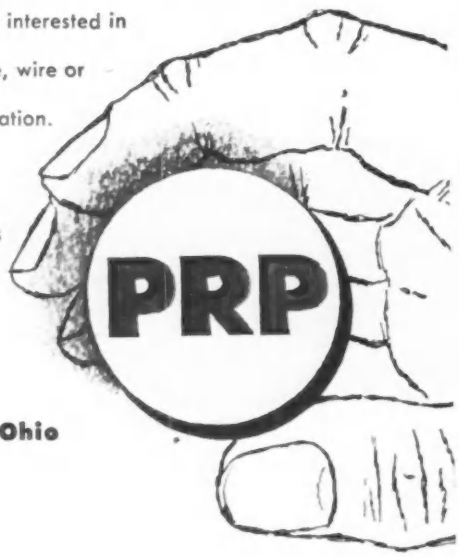

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Plastic Research Products

Urbana, Ohio

for equipments where available mounting space is limited. The model PM is Underwriters' Laboratory Rated at 15 amp @ 125 v a-c and 7½ amps @ 250 v a-c. Movement differential is 0.010 maximum. Operating force required is 7-11 oz and release force is 2-3 ounces. The unit is manufactured for the following circuits: single pole single throw, either normally open or normally closed; and single pole double throw.

The Sessions Clock Co., Tyniswitch Div., Forestville, Conn.

Safety Valve For Metal Drums

Ventadrum is a new safety valve designed to control and eliminate dangerous explosions caused by pressure expansions in 50 gal metal drums.

The valve is screwed into the bung opening of a universal type 50 gal drum, and has the following features:

It permits air to enter the drum on contraction of liquid or while it is being extracted; it permits air to escape during any expansion caused by temperature increase; fire screen prevents fire from traveling into the drum; it will not leak if drum turns over. Height is 3½ inches.

Central Safety Equipment Co., 2201 E. Huntingdon St., Phila. 25, Pa.

Small, Low Power Relay

This small, sensitive type N relay will operate on less than 50 milliwatts with a 10,000 ohm coil, 1 form C contract (spdt) and a standard adjustment. With a 450 ohm coil and four

School Daze!

Just because that bathing suit is proper at the beach, she shouldn't assume it's proper for the classroom, too!

And just because one bearing is best lubricated by one particular grade of oil, you shouldn't assume that the same oil is best for *all* bearings on that machine. In many cases it isn't.

OIL CUPS permit you to lubricate each bearing with the oil best suited to that bearing—thus prolonging bearing life, reducing maintenance costs, cutting down-time, boosting production. And oil cups fortunately *cost very little.*

Gits oil cups have been the standard for industry for more than 40 years. Gits Bros. has the largest selection of oil cups available anywhere. Call on Gits Bros. for a prompt, efficient solution to your lubrication problems.

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ONLY CURTIS OFFERS ALL THESE ADVANTAGES

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4 STAR TIMER

- ★ No false contacts
- ★ No chatter
- ★ Quiet in operation
- ★ Eliminates double contacting or breaking of circuit

HYDROGEN PACKED

Durakool
STEEL MERCURY TIMERS

The steel-clad "fixed time" Durakool timer-relay operates in "sealed in" hydrogen under pressure, with mercury to mercury contacts. Timing is tamperproof. Non-breakable and built for millions of contacts. Fixed time delays available from 1/6 to 20 seconds, either normally open or normally closed action.

See Telephone Directory for Local Distributor or write Durakool, Inc. Elkhart, Indiana

Send for Bulletin 800

form C contracts (4pdt) it will operate on 7/10 w, even under conditions of vibration and high ambient temperature.

High sensitivity results from the use of a close-coupled magnetic circuit, much magnetic iron, and efficient coil design. Other advantages are: high contact pressure, a minimum 30 grams; and adequate contact gap, a minimum 0.015 inch.

Type N relays are $1\frac{5}{8}$ in. long, $1\frac{3}{32}$ in. wide and $1\frac{5}{8}$ in. high with maximum of ten contact springs. Relays with not more than 14 terminals for coil and contact springs can be hermetically sealed in enclosures of extremely small size.

C. P. Clare & Co., 4719 W. Sunnyside Ave., Chicago 30, Ill.

Deflection Amplified Measures Short Pulses

A new wide band video amplifier, model V-2 is available which has a flat amplitude response of £1.5 db from below 10 cps to 20 mcps.

The wide band video amplifier is

designed for use as an oscilloscope deflection amplifier for the measurement and viewing of pulses of short duration and rise time. It is for laboratory and industrial use to extend the amplitude range of vacuum tube voltmeters and signal generators. The low frequency responses are said to permit accurate analysis of television signals. Sixty cycle square waves are passed with less than 5 percent tilt.

Polarad Electronics Corp., 100 Metropolitan Ave., Brooklyn 11, N. Y.

Sub-Miniature Control Unit

A sub-miniature control known as series 48 A is available as either a single or dual unit, and pressures only $\frac{3}{4}$ in. in diameter. The body depth of the single unit is $\frac{7}{16}$ in. while the double unit measures $\frac{53}{64}$ inch. The bushing is $\frac{1}{4}$ in. long, beyond which

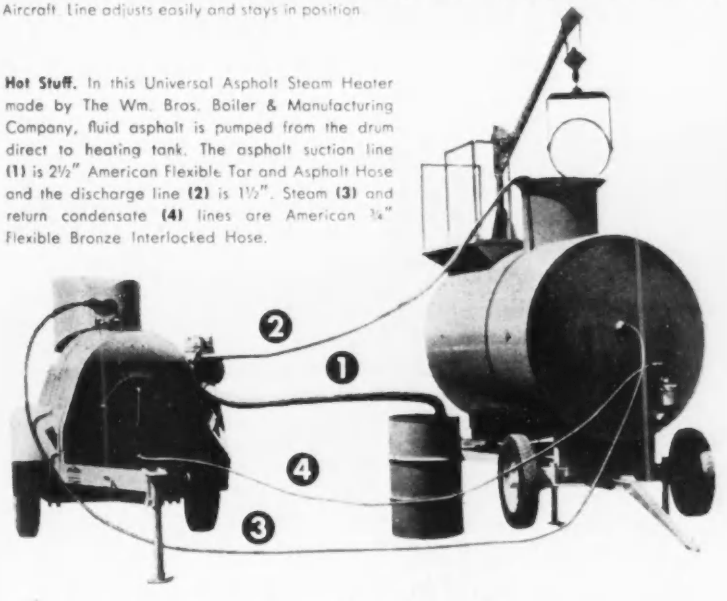
How in the world would **you** have solved these connector problems?

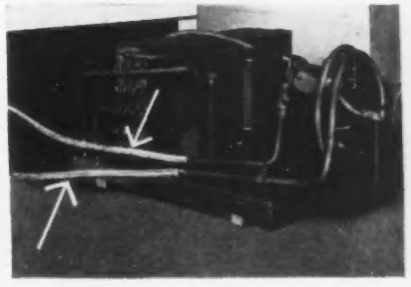
Coolant gets a new twist. A quick twist, and American Flexible Metal Tubing conveys coolant to just the right spot on this special lathe which machines jet engine parts at Pratt & Whitney Aircraft. Line adjusts easily and stays in position.

Would you have relied on costly, clumsy, rigid piping? Thrown up your hands? Or — like the resourceful designers of these three machines — would you have used flexible metal tubing? In each case American Flexible Metal Hose or Tubing filled the bill . . . and cut operating costs.

Your product, too, may need versatile, flexible American Metal Hose. If it must move, bend, or vibrate, let us show you the right connector...designed to absorb vibration, connect moving lines, or to be assembled in close quarters, while resisting heat, cold, pressure and corrosion in conveying liquids, gases or semi-solids. Write for Bulletins SS-50 and CC-300 which give technical details and many application histories. The American Brass Company, American Metal Hose Branch, Waterbury 20, Conn. In Canada: The Canadian Fairbanks-Morse Company, Ltd.

Hot Stuff. In this Universal Asphalt Steam Heater made by The Wm. Bros. Boiler & Manufacturing Company, fluid asphalt is pumped from the drum direct to heating tank. The asphalt suction line **(1)** is 2½" American Flexible Tar and Asphalt Hose and the discharge line **(2)** is 1½". Steam **(3)** and return condensate **(4)** lines are American ¾" Flexible Bronze Interlocked Hose.





Pull-out is a push-over to repair. Tyler Fixture Corp. neatly solved the problem of permitting quick inspection and easy repair of the refrigerating unit in their freezers. Entire unit pulls out, yet refrigerant lines remain connected — thanks to American Seamless Flexible Bronze Tubing.

ANACONDA

wherever connectors must move

American **FLEXIBLE METAL HOSE AND TUBING**

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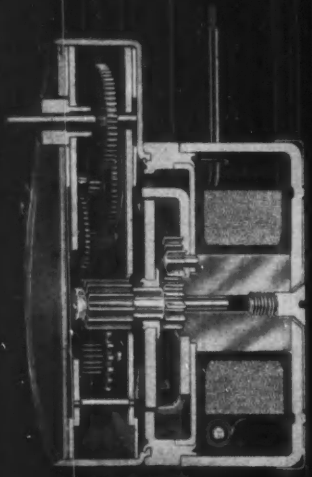
SYNCHRONOUS TIMING MOTORS

Cramer



Dependable, constant speed performance with exceptionally high torque make the Cramer Type SX Permanent Magnet Synchronous Motor your best possible choice for instrument and control applications. A thoroughly engineered product . . . produced under skilled technical supervision and proved in years of field service. Cramer Type SX Motors meet a wide range of specifications with clearly stated performance characteristics.

Torque 30 in. oz. at 1 r.p.m. Response so fast that motors reach synchronous speed in ½ to 2 cycles, stop within one pole of motion (1/60 sec.) on 240 r.p.m. rotor shaft.

Available with standard gear trains from 60 r.p.m. through 1/24 r.p.h. for 25, 50 and 60 cy. Also available in clutch type, chart drive and reversible units. (Patented controlled rotation either clockwise, counterclockwise or dual. Replaceable coils. U. L. approved.) Send for technical bulletins giving complete details and specifications.

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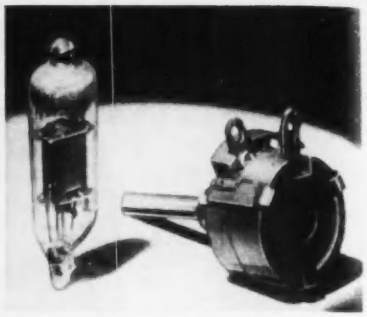
Builders of dependable timing devices for more than 25 years.

INTERVAL TIMERS • TIME DELAY RELAYS • RESET TIMERS • CYCLE TIMERS
PULSE TIMERS • RUNNING TIME METERS • PERCENTAGE TIMERS • SYNCHRONOUS MOTORS



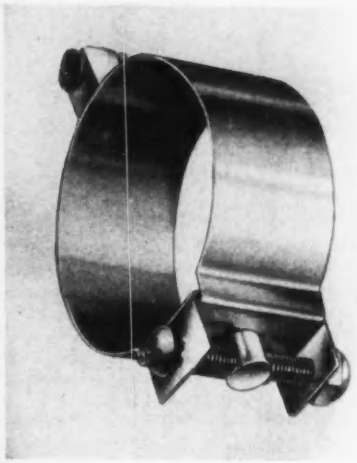
the shaft extends ½ inch. The shaft may be obtained as a flatted, or slotted tube. Standard shaft is ⅛ in. round of soft metal. The body of the new control is durable bakelite.

Series 48 A is available in either tapered, or linear resistances. The linear ranges are from 1000 ohms to 5 megohms. Tapered resistances run from 5000 ohms to 2.5 megohms.

Clarostat Mdg. Co., Dover, N. H.

Instrument Mounting Clamp Simplifies Servicing

An instrument mounting clamp has been perfected which permits removal of the instrument from the dial side of the panel. The clamp has a 2 in.



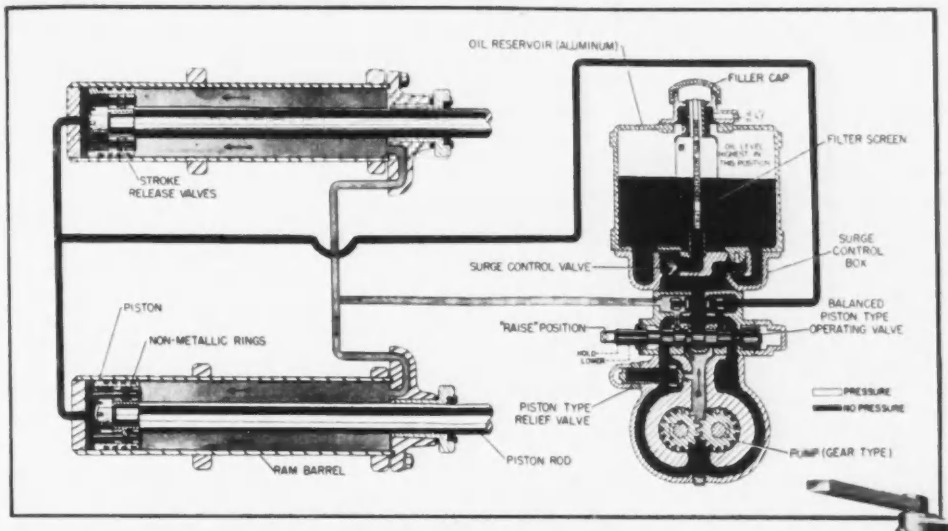
dia, and is installed on the rear of the panel behind the cutout. Fastening or removal is accomplished by adjusting only one clamp actuator screw, saving time in assembly and servicing.

Marman Products Co., Inc., Inglewood, Calif.

Titanium Carbide Thread Ring Gage

Thread ring gages made with a combination of titanium and carbide, a material called Demark, are light in

FOR THAT "Something Extra" IN PERFORMANCE



SPEED

POWER

VERSATILITY

SIMPLICITY

TROUBLE-FREE OPERATION

DESIGN YOUR PRODUCT WITH LaPLANT-CHOATE HYDRAULIC UNITS

FOR designers and manufacturers of products that can be improved by hydraulic operation, LaPlant-Choate Hydraulic Units give the performance "extras" which bring extra advantages into your competitive sales picture.

These powerful, smooth-operating units . . . jacks, pumps, valves or the compact, all-in-one fluid power control . . . supply the speed, flexibility, and instant response to controls that keep equipment operating economically and efficiently.

That's why so many manufacturers like the ones listed below are using LaPlant-Choate Hydraulic Systems for the utmost in full hydraulic operation. For complete details, send for Bulletin B-1152B, or write your requirements to LaPLANT-CHOATE MANUFACTURING CO., INC., Cedar Rapids, Iowa.

A few of the well-known manufacturers who make good products even better with LPC Hydraulic Units

Service Supply Corp. (Manufacturing Division) THE LODOVER	Pacific Car & Foundry Co. CARCO HYDRADOZERS	Municipal Supply Co. THE GUTTER SNIPE
The Warner & Swasey Co. GRADALL	Wm. Bros Boiler & Mfg. Co. BROS BULLDOZERS	Pittman Manufacturing Co. THE HYDRALIFT

THE FAMOUS LPC FLUID POWER CONTROL

Pump, valve and oil reservoir are all combined into a single compact unit that mounts on the front of the tractor behind the radiator guard. This new "closed system" design completely eliminates long suction lines, reduces the hazard of leaks and assures greatly increased speed and efficiency. In addition, the entire unit is skillfully engineered and precision built for utmost simplicity, easy servicing, and long, trouble-free operation.

LaPLANT CHOATE

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Thinking of Stainless?
Think of ALLMETAL
for the finest in
STAINLESS STEEL FASTENERS
MADE RIGHT —
By specialists in stainless steel since 1929.
PRICED RIGHT —
Because ALLMETAL uses modern equipment—including cold-heading machines—devoted solely to stainless.
RIGHT COMBINATION
For solving fastening problems quickly, economically.
Allmetal has the fasteners you want. Stock items, including Government and "AN" specs, shipped immediately. Prompt delivery on various types of Phillips Recessed Head screws and specials. Switch to Allmetal Stainless Fasteners when you switch to Stainless!
Use our "Rush Order" direct wire service — Send telegrams to "Allmetal Screw Products — WUX — New York." — that's all —
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ALLMETAL
Screw Products Co., Inc.
33 GREENE STREET, NEW YORK 13, N. Y.
STAINLESS STEEL FASTENERS

weight, and show very long wear life. After being tested for four years in production, and on assembly lines, a check on these gages showed no measurable wear.

A special wear check plug is provided with each ring to detect any possible wear. Every gage produced is a registered gage with a serial number engraved on the metal. Its lead, angle, diameter, and hardness are kept on file.

The Pipe Machinery Co., 938 E. 70 St., Cleveland, Ohio

Mercury Plunger Relay For Three Wire Operation

The new model-10 mercury plunger relay, which is used for three wire operation is said to offer good service for lock-up relays, off-on push button control, traffic light operation, and other applications. When contact is made, the in-put line connects to the two isolated circuits.

The tungsten contacts are hermetically sealed in vacuum or hydrogen filled glass tubes. Loads up to 35 amp at 115 v a-c or 25 amp at 220 v d-c can be handled by this new relay.

The sealed construction allows for safe operation under all operating conditions, and the elimination of exposed arc permits safe use in explosive atmosphere. The model EM-10 measures $3\frac{3}{8}$ in. wide, $4\frac{3}{8}$ in. high, and $2\frac{1}{4}$ in. deep.

Ebert Electronics Co., 185-09 Jamaica Ave., Hollis, L. I., N. Y.

Flexible, Bellows Type Pipe Connector

Fabricated of chemically inert teflon, a new bellows type connector has many pipe line applications where vibration, expansion and electrolysis exist in the handling of corrosive liquids or gases and solvents. The new connector is electrically non-conductive, flexible at —94 F, and as strong at 480 F as at 70 F, according to the manufacturer.

This bellows connector serves as a vibration dampener as well as an expansion joint. It connects misaligned couplings and insulates flanges electrically. End flanges of the joint are French-type envelope gaskets made integral with the joint for easy assembly between companion flanges and a tight, leakproof seal on installation.

Crane Packing Co., 1800 Cuyler Ave., Chicago 13, Ill.

"customer conscious..."

You are treated like a customer when you deal with The Bunting Brass & Bronze Company. It is a tradition in the Bunting organization to consider the good will of the customer as the most important factor in the transaction. Bunting customers find that Bunting resourcefulness no less than Bunting products, is made available when needed . . . Ask any Bunting customer.

The sleeve bearing is not complex in structure; it conforms readily to design requirements; it is easily installed. Cast Bearing Bronze is the most adaptable of all sleeve bearing materials; it possesses excellent anti-friction properties. With proper film lubrication, its coefficient of friction is as low as can be obtained with any other bearing type. A successful Bunting Bronze bearing installation is readily attainable. We ask the opportunity to work with you, and to quote on your requirements.

Bunting

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HEAT EXCHANGER COOLER or CHILLER

WHAT SHAPE? WHAT TYPE? WHAT MATERIAL?

for heating or cooling...

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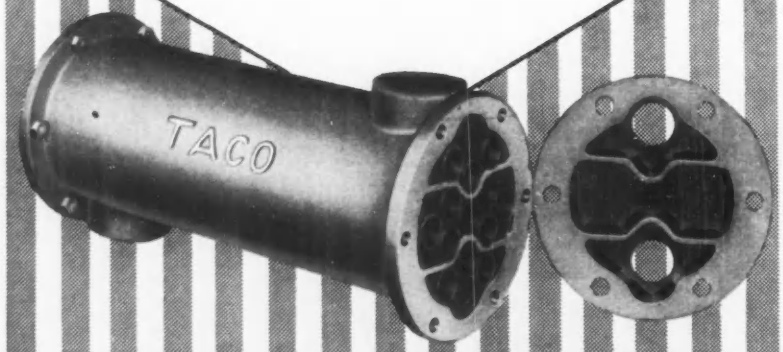
COOLANTS • CUTTING OILS • OTHER LIQUIDS

Our engineering department will gladly assist you, just as it has numerous other organizations, in design and selection of proper exchanger for your particular requirements.

A heat exchanger specialist from the factory is immediately available. Just call Providence, R. I., GAspee 1-2600, wire or write.



Illustrated is just one of more than 100 different shapes we are making as component parts for manufacturers.

Taco

TACO HEATERS INCORPORATED
137 South St., Providence 3, R. I.

MEETINGS

March 11-14

SOCIETY OF THE PLASTICS INDUSTRY—Fifth National Plastics Exposition, Convention Hall, Philadelphia, Penna.

March 17-21

AMERICAN SOCIETY OF TOOL ENGINEERS—Annual Meeting and Industrial Exposition, Chicago Amphitheatre, Chicago, Ill.

March 20-21

PRESSED METAL INSTITUTE—Spring Technical Meeting, Hotel Carter, Cleveland, Ohio.

March 22-April 6

CHICAGO INTERNATIONAL TRADE FAIR—Navy Pier, Chicago.

March 24-25

AMERICAN HOT DIP GALVANIZERS ASSOCIATION—Annual Meeting, Drake Hotel, Chicago, Ill.

March 24-26

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Spring Meeting, University of Washington, Seattle, Wash.

March 26-28

SOCIETY OF THE PLASTICS INDUSTRY, PACIFIC COAST SECTION—Annual Conference, Hotel del Coronada, Calif.

March 26-28

AMERICAN POWER CONFERENCE—Annual Meeting, Sherman Hotel, Chicago, Ill.

March 30-31

PACKAGING MACHINERY MANUFACTURERS INSTITUTE—Semi-Annual Meeting, Hotel Dennis, Atlantic City, N. J.

April 1-4

NATIONAL PACKAGING EXPOSITION AND CONFERENCE ON PACKAGING, PACKING AND SHIPPING—Atlantic City Auditorium, Atlantic City, N. J.

April 21-24

SOCIETY OF AUTOMOTIVE ENGINEERS—National Aeronautic Meeting and Aircraft Engineering Display, Hotel Statler, New York.

April 29-30

METAL POWDER ASSOCIATION—Annual Meeting and Show, Drake Hotel, Chicago, Ill.

THE *absolute* TEST OF STAINLESS STEEL CASTINGS IS IN YOUR OWN MACHINE SHOP!

Metallurgical analyses are important. Photomicrographs are good. But when the chips are down and production *has* to hump — smooth, trouble-free machining in your stainless steel castings is a positive *must* to keep down expense.

And that's what WAUKESHA FOUNDRY provides. But there's a bonus, too. Several, in fact. WAUKESHA Stainless Steel Castings are porosity-free (even to pinholes). They're dimensionally correct — and checked for it. Smooth in surface, close grained in section they give you cost-cutting, corrosion-resistant, exceptionally long wearing parts for the equipment you design and make.

Why? Because all WAUKESHA Castings are laboratory controlled from the foundry sand to the finished pieces. Not just occasionally — but every day!

Here's our offer: prove a WAUKESHA Casting by your own tests with a casting made from your own pattern! Fair enough? Just send that pattern along!

Heart of WAUKESHA'S quality and production control are the metallurgical laboratories. Daily tests of ingots, sand and every heat. Fully equipped for complete physical and chemical tests.

Give your corrosion-resistant casting problem to WAUKESHA to solve. Send along a blueprint and a description of performance requirements. Quite possibly WAUKESHA can save you money by recommending a formula in WAUKESHA METAL—a famous nickel alloy.

EQUIPPED TO SERVE YOU FROM BLUEPRINT *through the finished casting*

Waukesha Foundry Co.

1316 Lincoln Avenue
WAUKESHA, WISCONSIN

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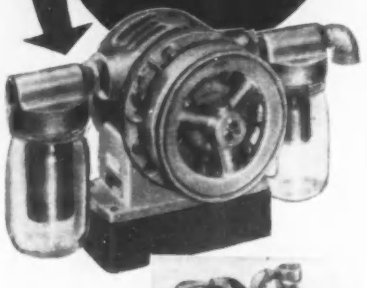
FORGET THE OIL!

GAST rotary Oil-less AIR PUMPS never need it!



Above — Oil-less Model 1550 — 8 to 10 C.F.M.
Right — Oil-less Model 3040, end plate removed. From 17 to 24 C.F.M.

Three things about these pumps are outstanding:

FIRST — They run *entirely without oil* in the pumping chamber. Four carbon vanes in rotor lubricate themselves — through thousands of hours of operation. Ball bearings are greased and sealed for life. You can *forget* oiling problems!

SECOND — They completely eliminate oil-mist in the air delivered. Used for *both* vacuum and pressure they *can't* contaminate your product or material with oil droplets.

THIRD — They're built with traditional Gast precision — for years of high performance and dependability.

IF THESE QUALITIES offer solutions to your original equipment problems, write Gast. Oil-less models from 10 to 20 inches vacuum — 3 to 10 lbs. pressure — 3.5 to 24 C.F.M.

SEND OUR CATALOG IN SWEET'S FILE

Write for new Data Sheet on Oil-less Pumps, showing 3 types and rating tables.

Original Equipment Manufacturers for Over 25 Years

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AIR MOTORS · COMPRESSORS · VACUUM PUMPS

(TO THREE H.P.) (TO 30 LBS.) (TO 28 INCHES)

GAST MANUFACTURING CORP., 839 Oakley St., Benton Harbor, Mich.

ENGINEERING ABSTRACTS

Nickel-Aluminum Bronze

Abstracted from "Nickel Aluminum Bronze" by J. S. Vanick, Foundry, Aug., September, 1951

Nickel additions to copper-base alloys containing 8 to 10.5 percent aluminum produce such beneficial effects as grain refinement, improvement of hardening qualities, mechanical strength and physical properties and increased resistance to corrosion.

Nickel aluminum bronzes exhibit good mechanical strength up to 750 F. Good oxidation resistance is provided by the formation of a tenacious, self-healing oxide film that forms at high temperatures. These alloys are used for moulds, dies, neck rings and plungers in glass manufacture and for service in steam plant equipment, internal combustion engines and in some chemical engineering applications. The higher nickel grades are used for high temperature service. Such an alloy would have a composition of 62 percent copper, 7 percent aluminum, 22 percent nickel, and 7 percent zinc, and a maximum of 1 percent iron and 0.25 percent lead.

The high hardness and strength of the 10/4/2.5 percent, aluminum-iron-nickel alloy (grade 9C of the A.S.T.M. specification) make possible its use for wear-resisting applications, especially those involving dry running, or actual abrasion. The retention of hardness at elevated temperatures is a useful feature in this type of service.

Aluminum bronzes having a Brinell hardness of the order of 200 possess machining characteristics resembling those of mild steel. Where especially high machinability is essential lead may be introduced, but the presence of lead hinders response to heat-treatment and is deleterious also in some other respects. Lead should be used with caution.

Nickel-aluminum bronzes can readily be welded, brazed, and hard- and soft-soldered. Difficulties at one time encountered in soft-soldering have been overcome by use of orthophosphoric acid as a flux.

The nickel-aluminum bronzes resemble steels in their response to heat-treatment, and the influence of nickel is closely similar in the two cases: its effect is to slow down transformation and stabilize structure: the mechanical properties of nickel-containing

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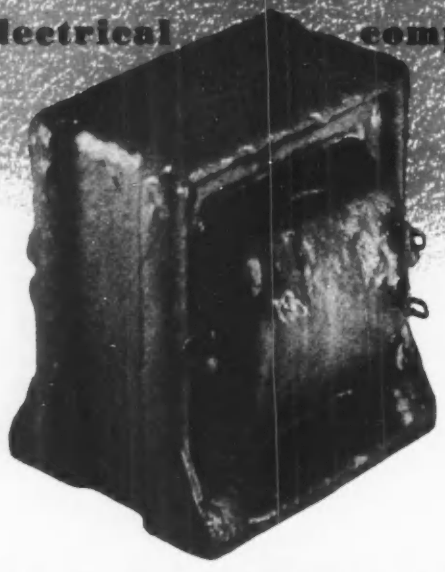

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aluminum bronzes may be varied over a relatively wide range by suitable heat-treatment conditions. A typical treatment for the 5 nickel, 5 iron, 10 aluminum alloy would consist in heating the casting at 1600-1650 F. (870-900 C.) for 1-3 hours, quenching, tempering for 1-3 hours at 1100-1150 F. (530-620 C.), and again quenching.

Modification of this heat-treatment (higher quenching temperatures or lower tempering temperatures), may be applied to develop higher hardness. Softening may be achieved by raising the tempering temperature or the time of treatment. It is considered that much work still requires to be done to establish fully the potential value of heat-treatment for these alloys, with particular reference to the modification obtainable by precipitation-hardening.

The final section of this article reviews some typical applications of the nickel-aluminum bronzes: these are noted below:

Aircraft Parts: propeller hub bushings and bearings, and fastenings; valve guides and valve seats.

Dies and Gears: dies, forming tools and fixtures, in which good hardness and low frictional drag can be secured; rolling-mill screw-down nuts, washers, slippers, etc.

Marine Engineering: ships' propellers, in which the cavitation-resisting qualities of the alloys are utilized; rudders, propeller caps and stern tube bearings are further applications, also various types of marine valve.

Power Plant: steam valves, pumps and accessories, combining the advantages of strength at elevated temperatures with high hardness and resistance to corrosion.

Electrical Equipment: welding-electrode holders, holders for electric motor brushes, transformer fittings, and certain tyes of switchgear, applications in which use is made of the almost non-magnetic character of the material, combined with its hardness and high strength.

Chemical Plant and Equipment: in various branches of this industry, e.g., paper, textile and petroleum plant, the corrosion-resisting qualities of the nickel-aluminum bronzes are of advantage, considered in conjunction with their physical and mechanical properties. In comparison with other copper-base alloys they give better resistance to gases containing sulphur dioxide, hydrogen sulphide, or low concentration of oxidizing acids.

Hydro-electric and Water Works: flood-control valves, pumps and hydro-electric control mechanisms represent current applications, also stems,

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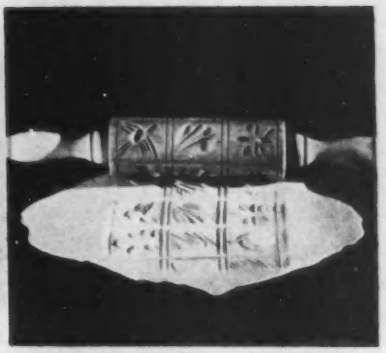
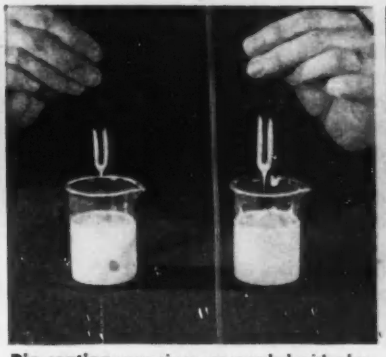
Continuous extrusion at room temperature. Plastigel quickly softens and flows easily when kneaded. Even hand pressure forms it into ribbon, rod, or tube. Fusing may be achieved by passing through hot CARBOWAX compound bath at 350°F. or oven baking.

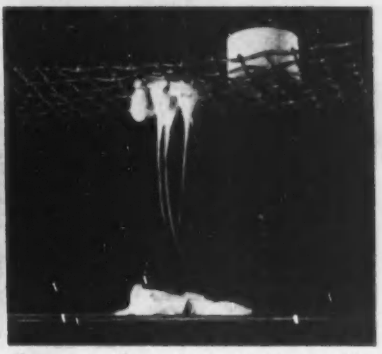


Low-pressure heatless embossing shown by use of intaglio rolling pin. Plastigel made from VINYLITE Resins also calenders readily, picks up details, retains them during subsequent fusing process. After fusing, this sheet will be tough, flexible, wear-resistant.

Quick-stamping operations are easy with plastigel formulations. Low pressure reduces die and equipment costs. Trimmings can be reworked. One mold serves for unlimited impressions because unfused plastigel stiffens and can be removed at once for baking.



Dip-coating operations are speeded with plastigel formulations of VINYLITE Brand Dispersion Resins. Plastigel (right) permits heavier coating in one application, is readily colored. Follows details closely, sticks fast, forming a tough, continuous, protective film.



Shape retention under heat is illustrated by this wire screen holding plastigel. Plastigel won't melt, sag, or run excessively. Standard plastisol (left) softens and runs through mesh when heated. Plastigel *hardens* in fifteen minutes at 350°F.

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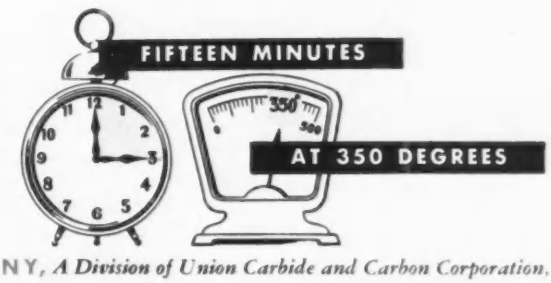

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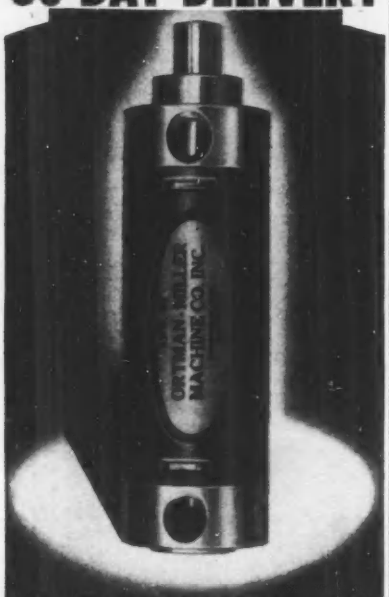

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Nickel-aluminum bronze castings in the lower-alloy range are being regularly made by permanent-mold processes, and vacuum-cast alloys of nickel-aluminum bronze are in daily production for hundreds of small castings.

Plastigels

Abstracted from "And Now The 'Plastigels' by Richard W. Quarles, Edward T. Severs, Arthur C. Frechtling, and Hugh S. Carpenter. Modern Plastics, January 1952.

ORGANIC LIQUIDS can be converted to gels by the addition of various thickening agents, such as metallic soaps. When these thickening agents are added to vinyl resin plastisols, the latter are converted to putty-like substances which have been given the name of "plastigels."

Plastigels may be extruded, calendered, molded, spread, embossed, or otherwise manipulated at room temperature under pressures that are not much above the pressures used for processing ordinary plastisols. Formed plastigels retain shape and detail during fusion at temperatures of 300 to 400 F.

As an example of the retention of detail, a sound recording was stamped into a plastigel. After fusion out of contact with the mold surface, the plastigel stamping was found to have picked up and retained the groove pattern with sufficient fidelity to play a recognizable tune on a phonograph.

Application of Plastigels

Plastigels may be handled by many of the conventional methods of fabricating plastics but the pressures required are lower, leading to lower machine and mold costs. Extrusion is one process particularly well adapted to plastigels. The pressures required for extrusion of plastigels are but a small fraction of those required for hot processing of vinyls. Die design is not difficult since, under the low pressures used, there is a little distortion in the extruded shapes. High speeds can be achieved because the products have sufficient cohesion so that they may be fused subsequent to extrusion.

Thick wall plastigel tubing of small diameter, as well as sheeting, has been extruded and subsequently cured by festooning in an oven without measurable distortion. Extrusion into a hot bath has proved even more desirable because of the supporting effect of the liquid and the faster heat transfer.

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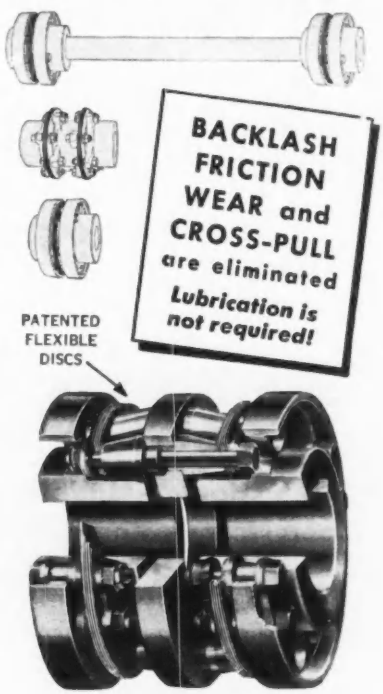

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fully fabricated with a low pressure rubber exttuder. It is probable that machinery designed for the extrusion of clay or ceramic products can be readily adapted to fabricating plastigels into pipe, tile, and similar products.

Calendering of plastigels under low pressures is feasible for coating cloth, paper, felt, and similar materials or for preparing unsupported sheets. The products are fused after calendering.

Molding and stamping offer promise as simple methods of fabricating plastigels. Very fast cycles are possible since the objects merely need to be formed in the mold and may be fused in a subsequent operation. Delicate inserts are not disturbed because only low pressures are required.

Unlimited Color Range

Compounds suitable for hand modeling have been made in an unlimited range of colors. Products range from a Shore A hardness of 100 to very soft. Filled compounds have much the same working characteristics as ordinary modeling clay, but with the advantage that they may be cured at temperatures available in a domestic oven. Models, flexible molds, tool handles, and orthopedic and prosthetic appliances are a few of the objects that have been molded from plastigels. The low density and non-shattering property of plastigels suggest that they may replace ceramics for equipment to resist inorganic acids and alkalies at room temperature. Caulking compounds and tailor-made gaskets which may be fused in place are other possibilities.

Since only low pressures are required to form plastigels, they can be applied as potting compounds for protecting coils and intricate electrical connections without disturbing delicate connections. Flexibility and low shrinkage during curing are valuable properties in this type of application.

Low Viscosity

Spreading on cloth or paper at high speed requires products of relatively low viscosity. Plastigels thinned with volatile diluents spread readily and after the mild drying required to evaporate the diluents regain their plastigel properties. Thus, plastigel coated products may be rolled, embossed, or otherwise handled before fusion if desired. Advantage can be taken of the control of flow offered by the plastigels to coat open-weave cloth or to prevent penetration of coatings into porous surfaces.

Heavy but uniform dip coatings are feasible with plastigels. It is not necessary to preheat the object before dip-

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.094††	x†	x†
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Wear of Metals

Abstracted from paper "Hardness, Elastic Modulus and Wear of Metals" by T. L. Oberle presented at SAE Annual Meeting, January 14-18, 1952, Detroit, Michigan.

PAST EFFORTS to reduce wear have always been aimed at increased strength and hardness of materials. This approach has been quite successful, but we are more and more frequently faced with ceiling limitations of maximum hardness which may be obtained. Additional gains are possible in the direction of minimizing the build-up of loads on metal surfaces. Reduced surface loads are obtained by reducing the elastic modulus of a material. The combination of high hardness with low modulus should result in superior wear resistant materials.

The limit of elasticity of metals, Figure 1, is that point where the stress-strain curve deviates from a straight line. This point may be iden-

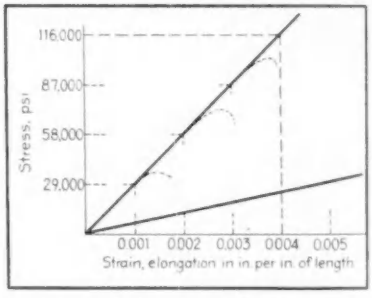
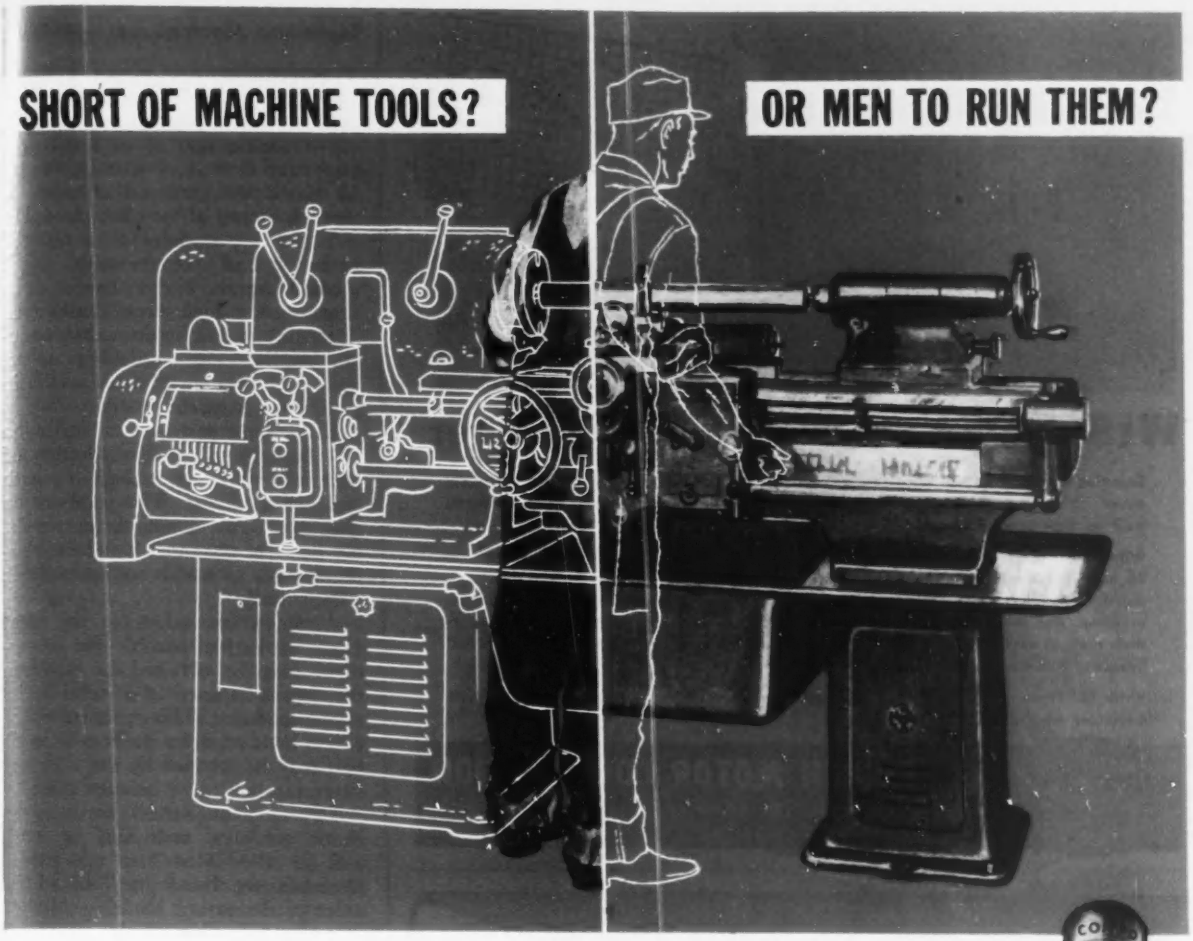


FIG. 1. Typical stress-strain diagram for metals.

tified as either the elastic limit of stress or the elastic limit of strain. The elastic limit of stress usually is reported for engineering materials as the yield strength of the material. The elastic limit of strain is seldom reported as such, but an indication of its magnitude can be obtained by dividing the elastic limit of stress of a material by its elastic modulus.

High hardness, sought after to increase wear resistance, actually increases the amount of elastic deformation that can be tolerated by a steel.



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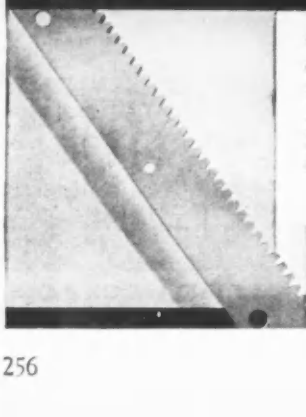

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Since the amount of elastic deformation may be important in wear phenomena, additional means of increasing it should also be explored. An important method of altering the total elastic deflection of materials is through control of the elastic modulus.

The elastic modulus of a material is the ratio of stress to strain. High modulus metals, Fig. 1, have a steep slope since a high stress causes relatively little elastic strain. Low modulus metals have a shallow slope, showing that a small stress results in a relatively large elastic strain.

Large amounts of elastic deflection may be achieved by the selection of materials which have high strength and low modulus. This combination does not occur commonly in metals, but both the elastic limit and the elastic modulus of metals are controllable within limits.

A convenient value for the total elastic deflection possible for a material may be obtained by dividing the Brinell hardness of a metal by its elastic modulus. This replacement of elastic limit of stress by Brinell hardness may be justified by the close relationship that exists between them.

The ratio of Brinell hardness to elastic modulus, multiplied by 106, will be called Modell in this paper. Materials are listed in Table I in order of decreasing Modell. Modell gives an indication of the depth of penetration that a metal can tolerate without exceeding its elastic limit. Chromium plate will recover elastically from more than 100 times the amount of deformation that will cause tin to plastically yield. Materials of high Modell behave like a spring, absorbing energy and preventing loads

TABLE I—Model Values for Various Materials

Material	Condition	Modell
Alundum (AL_2O_3)	Bonded	143
Chrome Plate	Bright	83
Gray Iron	Hard	33
Tungsten Carbide	9% Cobalt	22
Steel	Hard	21
Titanium	Hard	17
Aluminum Alloy	Hard	11
Gray Iron	As Cast	10
Structural Steel	Soft	5
Malleable Iron	Soft	5
Wrought Iron	Soft	3.5
Chromium Metal	As Cast	3.5
Copper	Soft	2.5
Silver	Pure	2.3
Aluminum	Pure	2.0
Lead	Pure	2.0
Tin	Pure	0.7

from building up to a high value.

The low Modell materials of Table I have little capacity for absorbing energy elastically. These low Modell materials are most suitable for use as bearings. Low melting metals such as lead or tin are essential to commercially acceptable bearing composition.

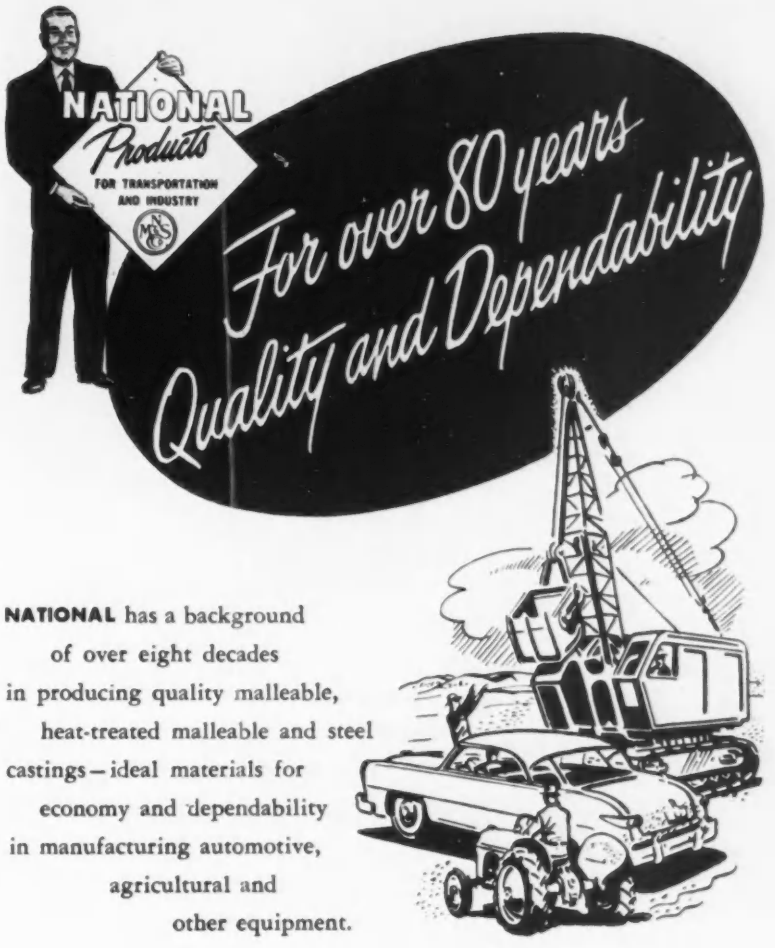
In addition to the inherent factors of melting temperature and atomic volume which determine the general level of elastic modulus, some metals are susceptible to variations in elastic modulus that may be controlled during the fabricating, casting, or heat treating stages of manufacture. Some controllable factors that may alter the elastic modulus of metals are heat treatment, interruptions, anisotropy.

The success of gray iron in resisting engine wear is attributed by some engineers to the lubricating qualities of the graphite. Yet, malleable iron with the same amount of graphite cannot be substituted successfully for gray iron in many engine parts. Some real differences in elastic properties between malleable and gray iron exist as a result of the shape of the graphite particle independently of the graphite volume.

Shuck reported elastic modulus, hardness, and wear on a number of gray irons cast in ¼ to 1½ inch square bars to produce graphite from coarse type A to fine eutectiform dispersion. Curves plotted from Shuck's data on seven unalloyed gray irons show: 1—Wear increases as hardness increases. 2—Wear decreases as elastic modulus decreases. 3—Wear decreases as Modell increases. Data from various sources indicate that for wear applications, gray iron should be cast with coarse graphite flakes and hardened by heat treatment to produce maximum Modell, rather than obtain high hardness in an as-cast, high-strength iron with resultant high elastic modulus.

Powder metallurgy techniques permit combining of extremely hard oxides, carbides, nitrides, etc. with a suitable binder to yield an aggregate of low elastic modulus. Current work on ceramic-metallic materials is centered around high temperature applications in jet engines. A bright future for ceramic-metallic materials exists in the field of wear applications.

As a general rule, the difficulties of machining increase with the hardness of the work. However, if the hardness is to be kept low for easy machining, the Modell value or wear resistance may be increased by lowering the elastic modulus of the material. Lowering elastic modulus improves resistance to wear and at the same time may improve machinability.



NATIONAL has a background of over eight decades in producing quality malleable, heat-treated malleable and steel castings—ideal materials for economy and dependability in manufacturing automotive, agricultural and other equipment.

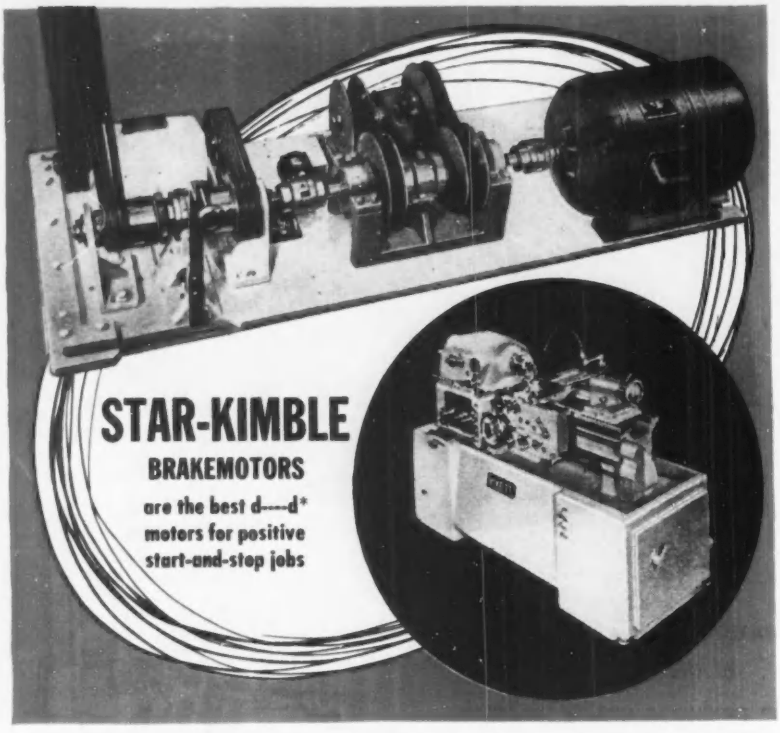
NATIONAL's unparalleled experience—coupled with a continuing metallurgical research program, rigorous quality control standards, and completely mechanized foundries in strategically located cities—is at your disposal.

Sales offices and engineering facilities are located at all five plants listed below.

A 16mm technicolor film. Narrated by Edwin C. Hill, this 27-minute film tells how malleable iron is made . . . tested . . . used . . . how its production economy, ductility, machinability, toughness will give you a better finished product. Available for group showings. A-5017

PLANTS LOCATED IN
Sharon, Pa., Cleveland 6, Ohio, Indianapolis 6, Ind., Melrose Park, Ill., and Chicago 50, Ill.

NATIONAL MALLEABLE and STEEL CASTINGS COMPANY
CLEVELAND 6, OHIO



CARRIAGE TRAVEL LIMITS HELD WITHIN .002"

...with Star-Kimble Brakemotors on Rivett Precision Lathes

Designed throughout for exceptional accuracy in both toolroom and production work, the 1020S Precision Lathe built by Rivett Lathe & Grinder, Inc., Boston, Mass., provides for stopping the carriage travel by means of limit switches. These switches control the power supply to a Star-Kimble Brakemotor.

Precision dial indicator shows the accuracy with which the Brakemotor stops the carriage at the predetermined point. According to the Chief Engineer of Rivett, the stop mechanism of the lathe has been operated an almost unlimited number of times. Accuracy of the stop has been *within .002"*, every time!

In thread cutting, the fast, accurate stopping of the Brakemotor permits the thread to finish up at identical positions on piece after piece.

Wherever applications call for accurate, positive, split-second stops—and *particularly* for repeated starts-and-stops in the toughest of duty cycles—Star-Kimble Brakemotors have proved their ability to run for years with little or no attention.

*Demanded by Industry

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STAR-KIMBLE

MOTOR DIVISION OF
MIEHLE PRINTING PRESS AND MFG. CO.
211 Bloomfield Avenue Bloomfield, New Jersey

Sans, Souci

Ad Libbing By The Editor

As the name, "Sans, Souci," of this column indicates, it is written without care. That fact was demonstrated last month in the story, "A Story in Three Pictures". That story as presented had a few errors in it for the simple reason that time marches on and we forget. And the worst of it is we cannot remember what we have forgotten. Otherwise it wouldn't be forgotten.

Anyhow my good friend Ralph Richardson of General Motors set me straight. As he analyzes it the three ads strikingly demonstrated the difficulty in getting a new invention or development into use. Just to review the subject, ad number one dated 1933 put the locomotive builder on record with "the factors which have kept steam the dominating power in American Railroading for over 100 years, will continue to keep steam the dominating power for railroad transportation for a long, long time to come." How long "a long long time" is was not stated. But it was only eight years later that the same company advertised that there was quite a problem to determine whether diesel or steam power would be used for a specific locomotive job. In this ad they candidly admitted that they couldn't tell, didn't know and wouldn't say offhand which type of locomotive would be used because each railroad problem would have to be analyzed separately. But whichever type of power fitted the job better, they could build it. And then seven years after that came the newspaper story announcing that the company would no longer build steam locomotives, and that all of their shop facilities would be turned over to manufacturing diesel-electric locomotives.

As Ralph Richardson pointed out to me, the two ads and newspaper clippings certainly demonstrated the tenaciousness with which we hang on to the old ways of doing things. But there is another important lesson to be learned from this experience. It is this: In only fifteen years the tremendously far flung railroad industry changed virtually completely from steam to diesel-electric. It is truly amazing that it should have taken only fifteen years to make the complete changeover when we stop to think of the tremendous capital investment involved. It is clearly indicative of the terrific impact of new scientific and

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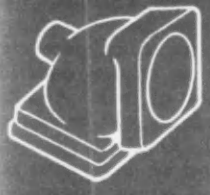
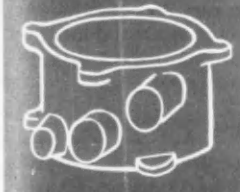
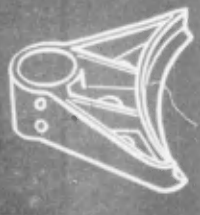






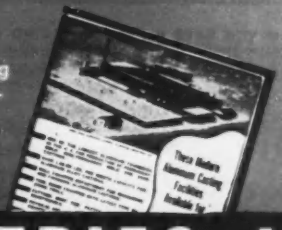
***DESIGN** — Recommendations made by Permite engineers for structural design changes based on the casting process, casting size, complexities or other factors, often bring the customer worthwhile savings and better casting performance.

***PRODUCTION** — Over 30 years of experience in working with aluminum and its alloys are behind the skill and "know how" of our metallurgists, engineers and foundry personnel.

***QUALITY** — Spectrographic analysis, X-ray inspection, Zyglo black light inspection, combined with other advanced inspection and quality control procedures guarantee the quality of Permite Castings.

***DELIVERY** — Permite's modern plants with a monthly capacity of over 2,500,000 lbs. of aluminum alloy castings, and ample warehouse facilities favorably located for shipping, assure delivery of your castings when you need them.

Write for Bulletin 20-A describing Permite complete facilities for serving your aluminum castings requirements. Send blueprints for recommendations and estimates.



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ALUMINUM INDUSTRIES, INC.

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DETROIT: 809 New Center Building. NEW YORK: 9 Rockefeller Plaza. CHICAGO: 64 E. Jackson Boulevard. ATLANTA: 413 Grant Building.

ALUMINUM PERMANENT MOLD, SAND and DIE CASTINGS...HARDENED, GROUND and FORGED STEEL PARTS

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No shortage of this PLASTIC

Here's a plastic material for molded parts that will probably always be available . . . with a favorable cost factor . . . no matter what happens. It's a good substitute for castings, die castings, and scarce plastics for many parts.

*ACE-TEX is a black pyrobituminous material that's best known for its use in ordinary auto battery cases. Containing no synthetic plastics or rubber, it has excellent dimensional accuracy, chemical resistance, and smooth finish. It's particularly suitable for box-shaped parts, containers, covers, etc.—even imitation bronze plaques. It can be painted or lacquered. Requires no cure time in molds—just cooling time. Take a look at these properties:

Specific Gravity	1.45-1.55
Tensile Strength, Psi.	1000-1800
Compression Strength, Psi.	4000
Transverse Strength—Modulus of Rupture, Psi.	2000-6000
Hardness at 77°F. Shore "D"	70-75
Coeff. of Expansion inch/Deg. C.	0.00005
Heat Distortion Temp. Deg. F.	135-180
Dielectric Strength, 60 cycles, v/mil	Over 200
Water Absorption	Extremely low; Practically nil.

IF YOU HAVE A PRODUCT FACING A MATERIALS SHORTAGE WHERE ACE-TEX MIGHT FIT, SEND US A SAMPLE AND ASK FOR RECOMMENDATIONS.

ACE-TEX is one of many hard rubber, synthetic rubber and other plastics molded, extruded and finished at our two plants. Write for valuable new ACE Handbook of hard rubber and plastics.

American Hard Rubber Company

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engineering developments on our way of living and our industrial machinery. It also indicates the speed with which new developments are taking place.

From Hot to Cold to Super Hot

Frozen foods are relatively new. Some freezers as we know them today have been on the market in a big way less than ten years. Frozen foods have been sold for a somewhat longer time. But recently there was an announcement that by means of a new quick super heating technique it is now possible to can fresh milk, fruit juices and the like. Claims are made that the foods canned by this method are far superior in taste, vitamins and nutrients than are the frozen foods. Maybe that is right and maybe it is wrong. I don't know. I am not a food expert. But let us assume that it is true. If it is true it will mean tremendous sweeping changes especially in the marketing of milk. Also the frozen food industry will be tremendously affected. Obviously so. The lesson here is that we must expect and be prepared to accept unsuspected rapid developments in science and technology. The rate of obsolescence is increasing because science is moving so fast that many products and methods are out of date even before they become firmly established.

Privileged Stubborness

Not long ago I came across a machine designed by Ordnance Department engineers. Perhaps it belongs on our secret list so I will not go into details. Anyhow this machine had some hydraulic cylinders on it which were of very unusual design. The peculiarity of the design was that the cylinders were assembled with the pistons in them and then each of the two cylinder heads was put into position and welded to the cylinder body. In other words, the cylinder ends could not be taken off again without destroying the whole unit. I asked the chief engineer how they expected to put in new packings or piston rings. He ruefully shook his head and said that they had called this whole matter to the attention of the Ordnance engineers and they refused to do anything about it. They insisted that the cylinder was to be made as designed. It is, however, to the credit of the Ordnance Department that soon afterward they had a new engineer in charge of the design and he immediately changed it to have the ends of the cylinders held on by means of screws, which is the way it should have been in the first place.

Maybe the original engineer was

fired because he had made too many mistakes of this nature. I don't know. Or maybe they promoted him to be a Colonel or a General. In any event, my first reaction was one of wonder that an engineer could be so stubborn as to refuse to acknowledge the obvious and glaring mistake in his design. It is always better to acknowledge a mistake gracefully and get the thing corrected than to attempt to bullheadedly brazen it out.

Unfortunately, it is human nature to argue about the mistakes we make. The mental process goes about this way. First we deny it as a mistake. Then when it is no longer possible to deny the fact that it is a mistake, the next tendency is to excuse it or blame it on someone else. When a situation such as this develops it is sometimes the fault of management.

There are always some bosses who take the position that everybody's mistakes, except their own of course, are unexcusable. They fail to recognize that any man who really accomplishes something must of necessity make mistakes. This is strikingly demonstrated in the development of any new machine even if it is another model of an existing design. As all engineers know, these new designs are full of "bugs". That sounds a lot better than calling them mistakes.

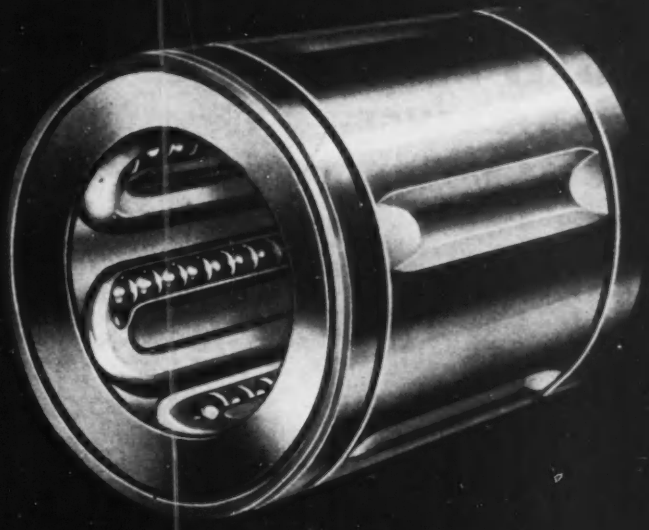
The men who are great leaders as heads of engineering departments are those who are rich in human understanding. Depending upon how the situation is handled by his superiors, the man who makes a mistake either learns something and becomes a better man or he is crushed and develops an inferiority complex. The greatest responsibility of a boss is to build men.

We Do Need Luck

There is a story of the little boy who read in his Horatio Alger book about another little fellow who went seeking an office job. According to the Alger story, the hero finally got into the office of a prospective employer and in his embarrassment he gazed around on the floor and saw a pin on the floor which he carefully picked up and put in a pin tray on the boss's desk. The boss said to the little fellow, "You are so careful of little things that I know you will be careful about big things." And he was hired immediately.

One day the little boy who had read this story went out to look for a job and he shuffled into the office of a prospective employer. He gazed around the floor. The employer was greatly puzzled when the youngster looked at him and said, "Gee! tough luck, no pin on the floor." —G. F. N.

BALL BUSHING



The BALL BEARING for your

LINEAR MOTIONS

Sliding linear motions are nearly always troublesome. Thousands of progressive engineers have solved this problem by application of the Precision Series A or Low-Cost Series B BALL BUSHINGS.

Alert designers can now make tremendous improvements in their products by using BALL BUSHINGS on guide rods, reciprocating shafts, push-pull actions, or for support of any mechanism that is moved or shifted in a straight line.

Improve your product. Up-date your design and performance with BALL BUSHINGS!

Now manufactured for 1/4", 1/2", 3/4", 1", 1 1/2" and 2 1/2" shaft diameters.

LOW FRICTION • LOW MAINTENANCE
ELIMINATES BINDING AND CHATTER
SOLVES SLIDING LUBRICATION PROBLEMS
LONG LIFE • LASTING ALIGNMENT

Progressive Manufacturers Use Ball Bushings
—A Major Improvement at a Minor Cost

THOMSON INDUSTRIES, Inc.

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Write for descriptive literature and the name of our representative in your city.

Also manufacturers of NYLINED Bearings — DuPont NYLON within a metal sleeve—for rotation and reciprocation.

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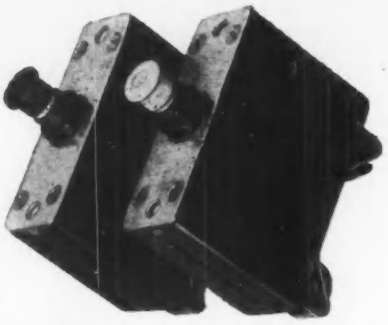
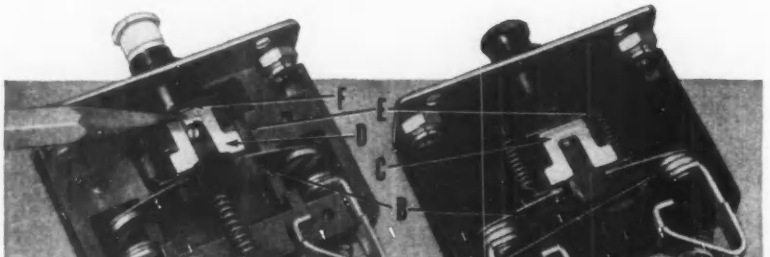
CHACE BIMETAL MAKES THE BIG DIFFERENCE IN THESE M-P BREAKERS



Product of:
Mechanical Products, Inc.
Jackson, Mich.

The only external difference in these miniature breakers manufactured by Mechanical Products, Incorporated, is that one is black and one olive drab. But the BIG difference is that the OD is Trip Free—i.e. cannot be maintained closed against serious overloads—while the black may be forced to contact. This factor is of extreme importance in blowers, heaters and other devices requiring positive protection but with limits on weight and space. The M-P breakers weigh 2 ounces.

Here's how they work:



Trip-Free Yellow Plunger
Type with contacts open

Non-Trip-Free Black Plunger
Type with closed contacts

When the plunger is pressed in, the element assemblies latch in the position as in the right hand view, closing contacts "A". The current then passes through blades "B" and thermostatic bimetal elements "C" and "D". Resistance of the elements causes them to heat up under overload currents. The upper ends of the U-shaped elements spread apart, the springs "E" trip the breaker and the plunger retracts bringing the element-blade assemblies with it as in the left hand view. The non-trip free (black) plunger (right) may be held in, making contact whether the condition is corrected or not. The trip-free (yellow) plunger, however, works freely in and out of the element, the movement being actuated by the small stop "F" which impinges normally against the top of the element. When the element opens up, the stop passes under and springs "E" move the element-blade assembly to open position. Contact cannot be forced. When the bimetal cools, the element closes up, the sloping boss (under pencil point) permits the stop to slide under the element again as the plunger is pulled out to reset, ready for action.

Chace Applications Engineers worked closely with Mechanical Products in the development of this intricate breaker and consultation is readily available should you have a problem in temperature-actuated devices. Chace Thermostatic Bimetal is available in strips, random coils or in complete elements. Write for our 64-page reference on thermostatic bimetal selection and element design.

W. M. CHACE CO.
Thermostatic Bimetal
1607 BEARD AVE., DETROIT 9, MICH.

OUR READERS SAY

Reprint Permission

To the Editor:

We would appreciate your giving us a release on the article entitled, "Stainless Steel Powder for Mechanical Parts," page 168 of the December, 1951 issue of PRODUCT ENGINEERING," so that we may distribute copies to the members of our industry.

—JEHU R. DERRICKSON
Formed Steel Tube Institute

Ed—We are glad to extend to you permission to reprint this article providing credit line is given to PRODUCT ENGINEERING.

Casting Article Stirs A Discussion

To the Editor:

In the article "Investment Casting: Alloy Selection and Design" by Ludwig and Wood from the November 1951 issue of Product Engineering, several statements appear which merit further consideration.

On Page 203, it is stated in the table that beryllium copper has "poor impact strength." This is misleading. In reality, beryllium copper has the best resistance to impact for a given level of strength or hardness of any of the copper-base alloys listed in the table. Impact values for silicon brass —described by the authors as having "good impact resistance"—are not readily available from the literature; however, National Bureau of Standards Circular C-477 gives an Izod value of 19 ft-lb for a silicon brass chill casting.

As previously indicated on page 242 of the August 1951 issue of Foundry, the 2 percent beryllium copper alloy offers the following Izod impact values in ft-lb.

Cast	65-80
Cast & aged	50-60
Cast & annealed	90-110
Cast & fully aged	5-11

Since annealed beryllium copper castings have a tensile strength of 60-70,000 psi which is equivalent to the upper end of the strength range for silicon brass, it is apparent that the impact resistance of beryllium copper is vastly superior to silicon brass. By under or over aging to re-

duce the impact level to 19 ft-lb the tensile strength of beryllium copper is increased to well over 100,000 psi.

In listing copper alloys in the order of their castability, the authors place red brass and phosphor bronze above beryllium copper. On page 81 of the January 1951 issue of *Materials & Methods*, they previously stated:

"The fluidity of the red and yellow brasses and bronzes is inferior to either beryllium copper or silicon brass, the latter of which is most generally credited with maximum fluidity. But the powerful deoxidizing effect of the beryllium in alloys containing it makes them as fluid as silicon brass when copper foundry melting equipment and controls suitable for handling the rather sensitive beryllium-containing metals are used."

This earlier statement on the excellent fluidity of beryllium copper agrees with reports received from foundries regularly handling this alloy. It should be pointed out, however, that uniformity is not difficult to control, provided reasonable care is exercised.

Beryllium copper casting alloys are not particularly sensitive with respect to composition, so that a single aging treatment can be applied to alloys ranging from 1.6 to 2.9 percent beryllium. Under normal melting conditions, beryllium losses average 0.12 percent so that scrap can be safely remelted several times without affecting hardening response.

In our own operations, we have successfully applied a single aging treatment (3 hr at 600 to 650 F) with our 2 percent beryllium casting alloy for a number of years. In handling the many heats run over this period of time, standard brass or bronze foundry equipment and techniques have been employed with good results. Oxidation, which is held to a minimum does not influence hardness response and, being largely confined to the surface, is readily removed by usual cleaning procedures.

—J. T. RICHARDS
The Beryllium Corp.
Reading, Pa.

Ed—". . . semantic differences," was the author's comment. A detailed reply appears below.

To the Editor:

The comments made by Mr. Richards are largely based upon semantic differences, and the nature of the tables presented in our article compelled us to condense our comments as much as possible. A fuller explanation of the points of issue follows:

Our reference to poor impact strength referred to the beryllium cop-

AMERICAN CHEMICAL PAINT COMPANY

AMBLER CHEMICALS ACP PROCESSES PENNA.

Technical Service Data Sheet

Subject: IMPROVING PAINT ADHESION ON STEEL WITH GRANODINE®

INTRODUCTION

"Granodine" is a zinc phosphate coating chemical which improves paint adhesion on steel, iron and zinc surfaces. In the Granodizing process, a non-metallic crystalline coating is formed on the treated metal. This bond holds and protects the paint finish and thus preserves the metal underneath.

Official Dept. of Defense Photograph

An F4U Corsair with the Navy's new aircraft anti-tank rocket, the "RAM". A Grade I zinc phosphate finish (JAN-C-490) protects the entire external surface of this rocket and provides a durable bond for the specification paint finish.

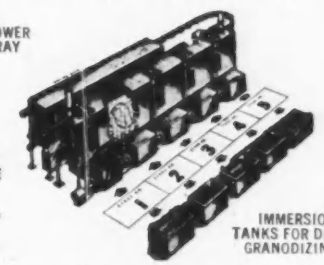
"GRANODINE" MEETS SERVICE SPECIFICATIONS

JAN-C-490, Grade I	CLEANING AND PREPARATION OF FERROUS METAL SURFACES FOR ORGANIC PROTECTIVE COATINGS
JAN-F-495	FINISHES FOR EQUIPMENT HARDWARE
U.S.A. 57-0-2C Type II, Class C	FINISHES, PROTECTIVE, FOR IRON AND STEEL PARTS
U.S.A. 51-70-1, Finish 22.02, Class C	PAINTING AND FINISHING OF FIRE CONTROL INSTRUMENTS; GENERAL SPECIFICATION FOR
MIL-V-3329	VEHICLES, COMBAT, SELF-PROPELLED AND TOWED; GENERAL REQUIREMENTS FOR

GRANODIZING DATA

Granodizing is an easily applied chemical process. Depending on the size, nature and volume of production, Granodizing can be carried out by spraying the parts in successive stages of a power washing machine, by dipping the work in the cleaning, rinsing and coating baths contained in tanks, or by brushing or flow coating the work with portable hand equipment. Typical process sequence and equipment requirements are shown below:

MULTI-STAGE POWER WASHER FOR SPRAY GRANODIZING



PROCESS SEQUENCE
1. Clean
2. Rinse
3. "Granodine"
4. Rinse
5. Final Rinse

IMMERSION TANKS FOR DIP GRANODIZING

NOTE: Equipment can be of mild steel throughout, except in the Granodizing stage, where nozzles, risers, and pump impeller should be of acid-resistant material.

MANY APPLICATIONS

Automobile bodies and sheet metal parts, refrigerators, washing machines, cabinets, etc.; projectiles, rockets, bombs, tanks, trucks, jeeps, containers for small arms, cartridge tanks, 5-gallon gasoline containers, vehicular sheet metal, steel drums and, in general, products constructed of cold-rolled steel in large and continuous production are typical of the many products whose paint finish is protected by "Granodine".

CHEMICALS ACP PROCESSES

WRITE FOR FURTHER INFORMATION ON "GRANODINE" AND YOUR OWN METAL PROTECTION PROBLEMS.

CHEMICALS ACP PROCESSES

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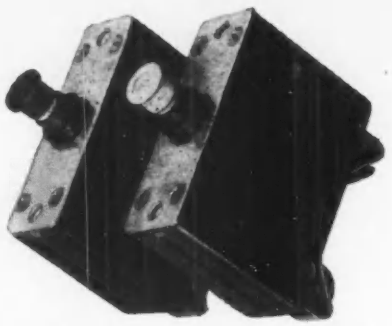
A Bit of

CHACE BIMETAL MAKES THE BIG DIFFERENCE IN THESE M-P BREAKERS



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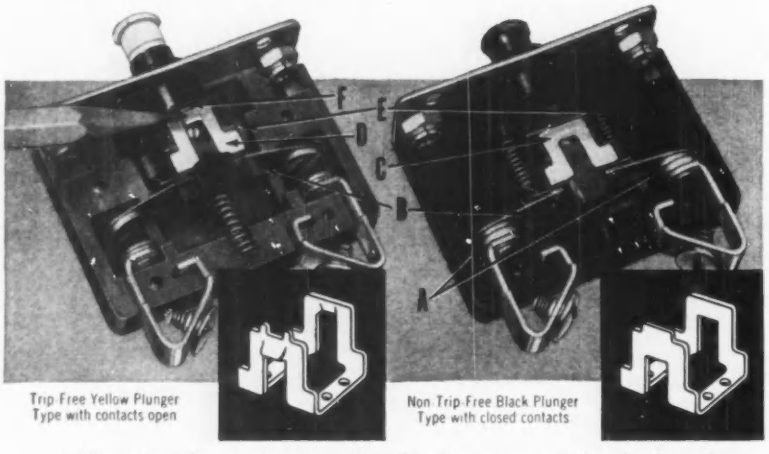

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W. M. CHACE CO.
Thermostatic Bimetal
1607 BEARD AVE., DETROIT 9, MICH.

OUR READERS SAY

Reprint Permission

To the Editor:

We would appreciate your giving us a release on the article entitled, "Stainless Steel Powder for Mechanical Parts," page 168 of the December, 1951 issue of PRODUCT ENGINEERING," so that we may distribute copies to the members of our industry.

—JEHU R. DERRICKSON
Formed Steel Tube Institute

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Casting Article Stirs A Discussion

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In the article "Investment Casting: Alloy Selection and Design" by Ludwig and Wood from the November 1951 issue of Product Engineering, several statements appear which merit further consideration.

On Page 203, it is stated in the table that beryllium copper has "poor impact strength." This is misleading. In reality, beryllium copper has the best resistance to impact for a given level of strength or hardness of any of the copper-base alloys listed in the table. Impact values for silicon brass —described by the authors as having "good impact resistance"—are not readily available from the literature; however, National Bureau of Standards Circular C-477 gives an Izod value of 19 ft-lb for a silicon brass chill casting.

As previously indicated on page 242

PAGES 2
264 MI

duce the impact level to 19 ft-lb the tensile strength of beryllium copper is increased to well over 100,000 psi.

In listing copper alloys in the order of their castability, the authors place red brass and phosphor bronze above beryllium copper. On page 81 of the January 1951 issue of *Materials & Methods*, they previously stated:

"The fluidity of the red and yellow brasses and bronzes is inferior to either beryllium copper or silicon brass, the latter of which is most generally credited with maximum fluidity. But the powerful deoxidizing effect of the beryllium in alloys containing it makes them as fluid as silicon brass when copper foundry melting equipment and controls suitable for handling the rather sensitive beryllium-containing metals are used."

This earlier statement on the excellent fluidity of beryllium copper agrees with reports received from foundries regularly handling this alloy. It should be pointed out, however, that uniformity is not difficult to control, provided reasonable care is exercised.

Beryllium copper casting alloys are not particularly sensitive with respect to composition, so that a single aging treatment can be applied to alloys ranging from 1.6 to 2.9 percent beryllium. Under normal melting conditions, beryllium losses average 0.12 percent so that scrap can be safely remelted several times without affecting hardening response.

In our own operations, we have successfully applied a single aging treatment (3 hr at 600 to 650 F) with our 2 percent beryllium casting alloy for a number of years. In handling the many heats run over this period of time, standard brass or bronze foundry equipment and techniques have been employed with good results. Oxidation, which is held to a minimum does not influence hardness response and, being largely confined to the surface, is readily removed by usual cleaning procedures.

—J. T. RICHARDS
The Beryllium Corp.

263 AND MISSING

AMERICAN CHEMICAL PAINT COMPANY

AMBLER CHEMICALS ACP PROCESSES PENNA.

Technical Service Data Sheet

Subject: IMPROVING PAINT ADHESION ON STEEL WITH GRANODINE®

INTRODUCTION

"Granodine" is a zinc phosphate coating chemical which improves paint adhesion on steel, iron and zinc surfaces. In the Granodizing process, a non-metallic crystalline coating is formed on the treated metal. This bond holds and protects the paint finish and thus preserves the metal underneath.

Official Dept. of Defense Photograph

An F4U Corsair with the Navy's new aircraft anti-tank rocket, the "RAM". A Grade I zinc phosphate finish (JAN-C-490) protects the entire external surface of this rocket and provides a durable bond for the specification paint finish.

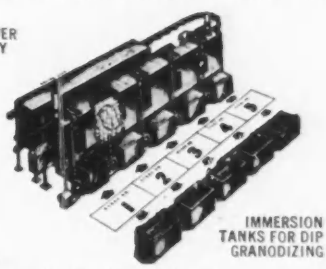
"GRANODINE" MEETS SERVICE SPECIFICATIONS

JAN-C-490, Grade I	CLEANING AND PREPARATION OF FERROUS METAL SURFACES FOR ORGANIC PROTECTIVE COATINGS
JAN-F-495	FINISHES FOR EQUIPMENT HARDWARE
U.S.A. 57-0-2C Type II, Class C	FINISHES, PROTECTIVE, FOR IRON AND STEEL PARTS
U.S.A. 51-70-1, Finish 22.02, Class C	PAINTING AND FINISHING OF FIRE CONTROL INSTRUMENTS; GENERAL SPECIFICATION FOR
MIL-V-3329	VEHICLES, COMBAT, SELF-PROPELLED AND TOWED; GENERAL REQUIREMENTS FOR

GRANODIZING DATA

Granodizing is an easily applied chemical process. Depending on the size, nature and volume of production, Granodizing can be carried out by spraying the parts in successive stages of a power washing machine, by dipping the work in the cleaning, rinsing and coating baths contained in tanks, or by brushing or flow coating the work with portable hand equipment. Typical process sequence and equipment requirements are shown below:

MULTI-STAGE POWER WASHER FOR SPRAY GRANODIZING



PROCESS SEQUENCE
1. Clean
2. Rinse
3. "Granodine"
4. Rinse
5. Final Rinse

IMMERSION TANKS FOR DIP GRANODIZING

NOTE: Equipment can be of mild steel throughout, except in the Granodizing stage, where nozzles, risers, and pump impeller should be of acid-resistant material.

MANY APPLICATIONS

Automobile bodies and sheet metal parts, refrigerators, washing machines, cabinets, etc.; projectiles, rockets, bombs, tanks, trucks, jeeps, containers for small arms, cartridge tanks, 5-gallon gasoline containers, vehicular sheet metal, steel drums and, in general, products constructed of cold-rolled steel in large and continuous production are typical of the many products whose paint finish is protected by "Granodine".

CHEMICALS ACP PROCESSES

WRITE FOR FURTHER INFORMATION ON "GRANODINE" AND YOUR OWN METAL PROTECTION PROBLEMS.

CHEMICALS ACP PROCESSES

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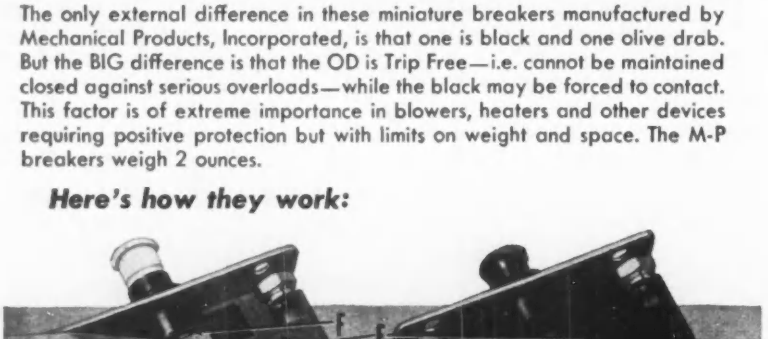
A Bit of

CHACE BIMETAL MAKES THE BIG DIFFERENCE IN THESE M-P BREAKERS

Product of:
Mechanical Products, Inc.
Jackson, Mich.

The only external difference in these miniature breakers manufactured by Mechanical Products, Incorporated, is that one is black and one olive drab. But the BIG difference is that the OD is Trip Free—i.e. cannot be maintained closed against serious overloads—while the black may be forced to contact. This factor is of extreme importance in blowers, heaters and other devices requiring positive protection but with limits on weight and space. The M-P breakers weigh 2 ounces.

Here's how they work:



Trip-Free Yellow Plunger
Type with contacts open

Non-Trip-Free Black Plunger
Type with closed contacts

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As previously indicated on page 242 of the August 1951 issue of Foundry, the 2 percent beryllium copper alloy offers the following Izod impact values in ft-lb.

Cast	65-80
Cast & aged	50-60
Cast & annealed	90-110
Cast & fully aged	5-11

Since annealed beryllium copper castings have a tensile strength of 60-70,000 psi which is equivalent to the upper end of the strength range for silicon brass, it is apparent that the impact resistance of beryllium copper is vastly superior to silicon brass. By under or over aging to re-

duce the impact level to 19 ft-lb the tensile strength of beryllium copper is increased to well over 100,000 psi.

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—J. T. RICHARDS
The Beryllium Corp.
Reading, Pa.

Ed—". . . semantic differences," was the author's comment. A detailed reply appears below.

To the Editor:

The comments made by Mr. Richards are largely based upon semantic differences, and the nature of the tables presented in our article compelled us to condense our comments as much as possible. A fuller explanation of the points of issue follows:

Our reference to poor impact strength referred to the beryllium cop-

AMERICAN CHEMICAL PAINT COMPANY

AMBLER CHEMICALS ACP PROCESSES PENNA.

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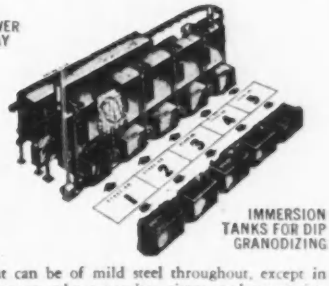

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CHEMICALS ACP PROCESSES

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We honestly believe that LUSTER-ON® offers you the most uniform and brightest finish for zinc plate at the lowest cost, under good or adverse conditions. What's more we'll prove it! Just ask us.
The Chemical Corporation – 59 Waltham Ave., Springfield 9, Mass.

per in a fully heat tested condition, and Mr. Richards' letter shows that in this condition impact strength is only 5-11 ft-lb compared to the 19 ft-lb for silicon brass. Of course the beryllium copper has a higher tensile strength in this condition than silicon brass can possibly attain. But the chief reason for using the more expensive beryllium alloy in casting is to obtain this superior tensile strength, and in practice almost all of the beryllium copper castings which we have been called upon to furnish are used in this fully heat treated condition. We therefore think that our comment of poor impact strength in heat treated condition is accurate.

In comparing our table with comments made in an issue of Materials & Methods, Mr. Richards assumes that fluidity is the only quality of importance in determining the casting properties of a metal. We grant that beryllium copper is more fluid than red brass or phosphor bronze. This advantage is offset in practical operation by the need for closer controls in alloying and melting the metal.

Our comment about the difficulty of maintaining uniformity should also be amplified. Mr. Richards states that beryllium losses averages 0.12 percent per melt. When a typical naval specification, such as Navy 46011 allows only a range of 0.20 percent it is obviously a matter of careful calculation at each heat to be sure that the specification is met. This is especially true if the original copper alloy ingot coming into the foundry is near the lower part of the range so that even the first melt is in danger of running under the minimum requirements of the specification. If the actual beryllium composition of the alloy is as unimportant as Mr. Richards claims, these specifications are unnecessarily strict. We would be very glad to see them opened up, and would be glad to cooperate with the Beryllium Corporation toward that end.

—Rawson L. Wood

Flow Chart Debate

To the Editor:

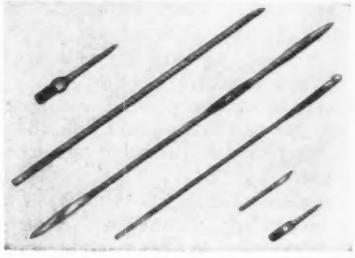
A novel flow conversion chart appears on page 197 of December 1951 Product Engineering by Nils M. Sverdrup. His method involves angles and tangents. It is susceptible to considerable graphical error and requires several lines for each solution. I fail to see any advantage over the three parallel line nomograph, which needs only one computing secant.

Let g be the specific gravity (as 1)

CUT COSTS

have your metal parts precision-made by

TORRINGTON



Special equipment and volume production enable us to make precision parts for you at much lower costs.

For example, highest quality special needles for textile, leather, paper, etc., machinery. Pins for printing presses and surveyors' instruments. Special equipment assures proper heat-treatment . . . accurately formed eyes, grooves and shanks . . . precisely sharpened points . . . clean milling, knurling, slotting, and bevelling. Needles hand-straightened.

We are also set up to make such parts as knurled mandrels and spindles, screw driver and ice pick blades, instrument shafts and pivots, surgical and dental instruments, pen and pencil barrels, special rollers, studs, dowel pins, etc.

Send your prints and specifications today for a prompt quotation.

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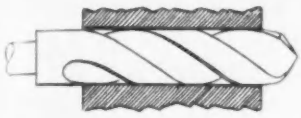
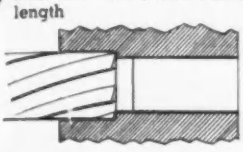
Specialty Department
554 Field Street • Torrington, Conn.

Makers of
TORRINGTON NEEDLE BEARINGS

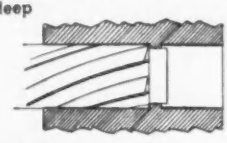
THE OLD WAY



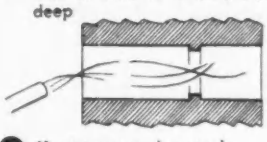
1. Drill 25.5 m.m. (1.004") hole full length



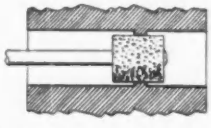
2. Machine bore to 1.761", .9975" deep



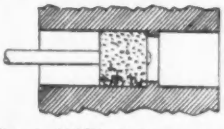
3. Rechuck and machine opposite end of bore to 1.761", 1.9355" deep



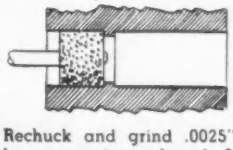
4. Heat treat and quench



5. Grind .00355" off shoulder inside diameter



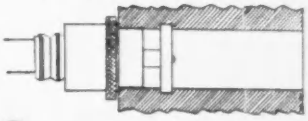
6. Grind .0025" off bore, one end and 0025" off side of shoulder



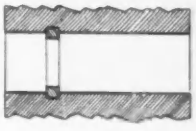
7. Rechuck and grind .0025" off bore, opposite end and .0025" off side of shoulder

RELIANCE WAY

1. *Drill 1.811" (30 M.M.) hole, full length



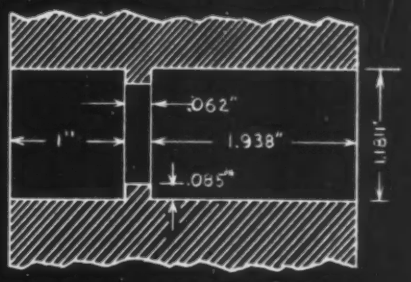
2. Recess groove .074" wide and .040" deep in bore, 1" from end

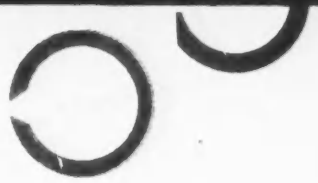


3. Snap Reliance Ring in groove

* For some applications, seamless tubing may be used, eliminating all drilling

No heat treating is normally required as ring is already hardened. No danger of warpage. If bore must be hardened, it may be ground in one pass after heat treating.





HOW RELIANCE RINGS
(AND GROOVING TOOL)
Slash the Cost
of internal shoulders

The drawing and comparison chart above show how Reliance Rings and the Reliance Grooving Tool slashed the cost of internal shoulders on a typical application, eliminating four operations — savin gtime and money.

Reliance Snap Rings are available in carbon, alloy, stainless steel or non-ferrous metal to specified physicals, cross sections and diameters—ends shaped to meet any requirement. Reliance Rings offer opportunities for cost reduction, time saving and product improvement limited only by human ingenuity in finding new uses for them.

Reliance engineers will be pleased to study your prints or parts and lend the benefit of their experience in considering possible application of Reliance Rings to your product. Or, if you prefer, a competent representative will call to discuss the possibilities with you. Write, phone or wire your nearest Reliance Sales Office

RELIANCE RINGS

MANUFACTURING COMPANY, RELIANCE DIVISION

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SAN FRANCISCO • MONTREAL

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WILL KEEP YOUR ASSEMBLY LINES AT PEAK CAPACITY

Whatever you manufacture or assemble, you can speed production and improve your product by using Pheoll screws, bolts and nuts. These industrial fasteners drive easy and straight, and will not bind because threads are accurately rolled or machined. Precision-made screw and bolt heads, slots and head recesses prevent wrench and driver slippage. Count, too, the added bonus you receive by using fasteners that improve product appearance.

An interesting story on standard and special industrial fasteners and their profitable applications to your needs may be obtained from experienced Pheoll engineers. Ask these men to recommend screws, bolts and nuts that will increase your overall profits on assembly line work.

w be the weight in lbs per second of the liquid flow (as 1.3)

v be the volume in cu. in. per second of the liquid flow (as 36)

V be the volume in gallons per minute of the liquid flow (as 9.4)

The above quantities satisfy these two equations which are derived from his chart:

$$g = \frac{27.7w}{v} \quad \text{and} \quad g = \frac{7.25w}{V}$$

To combine the two as a nomograph, draw three equidistant parallel lines, and mark them g, w, (v.V). Draw any straight line across these scales and mark the above numerical values on the line at the several scales. From these points graduate the scales using modulus of the middle scale half that of the outer scales. On the right scales graduate v on the left side and V on its right. This is in effect superposing the nomographs with the g and w scales in common and the right scale doubly graduated.

This single computing secant shows that a flow of 1.3 lbs per second of a liquid of sp gr 1 will have a flow of 36 cu in. per second or of 9.4 gal. per minute. It also shows a solid object weighing 1.3 lbs, immersed in any liquid and displacing 36 cu in. has a sp gr of 1. Also that 36 cu in. per sec equals 9.4 gal. per minute.

A second secant has been drawn for a different problem using these computed values: .78 1.84 65.5 17 which, if placed on the scales starting at left will be found to lie in a straight line. This checks the calculations with the graduations.

—CARL P. NACHOD
Nachod & U. S. Signal Co. Inc. Louisville, Ky.

Ed—We asked Mr. Sverdrup to comment on this criticism. His reply is below.

To the Editor:

I have read Mr. Nachod's comments but fail to see that the Flow Rate Conversion Chart published in the December 1951 issue of PRODUCT ENGINEERING is susceptible to graphical errors, and that the construction involves angles and tangents. When properly constructed on standard rectilinear graph paper with 20 divisions to the inch the flow rates can be read with a high degree of accuracy due to the precision of the divisions of the graph paper, and the large graduations of the specific gravity scale. The radius intersecting the specific gravity scale is the only construction line required in reading the chart. The specific gravity graduations of the arc

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WRITE FOR CATALOG

This Monarch advertisement originally appeared in July, 1948

MEET JOHN DOE...
"Retired" LOW BIDDER!
...or did you know him before he retired?
He could invariably undersell his competitors. He won the contracts but he lost his business... for he couldn't reduce his operating costs in proportion to the reduced prices he offered.
But, he's happy...hasn't a worry in the world. Why should he? His customers are holding the bag ...and that could mean any of us, for you'll find John Does in most every type of business.
Let's face the facts! We understand your desire for low prices. Our problems are no different from yours. Material prices are spiralling, labor costs are increasing and sound planning to develop end production to the lowest economical cost level is more important than ever.
The lowest price is not always the cheapest price ... but, the lowest cost of operation is a tangible asset in any production program. For 35 years, Monarch has developed low operating costs for manufacturers, everywhere, as a sound economical solution to their casting problems. We can do the same for you...Now!
ETHODS IN 1 MODERN PLANT
ALUMINUM PERMANENT MOLD
ALUMINUM DIE CASTING
ZINC DIE CASTING
MPANY
EVELAND 2, OHIO
FOR Quality SPECIFY Monarcast

...Under the stress of today's unusual economy, the important message it conveys is more significant than ever!

RELIABILITY OF SUPPLIER SOURCES is one of the most important elements in any successful program of industrial production. Today's "guns and butter" economy proves it.

With 38 years of experience to call upon, Monarch is in an outstanding position to help any company whose current production requirements include aluminum permanent mold, aluminum or zinc die castings or complete sub-assembly work.

Monarch is ready to serve you now...with modern facilities and processes and people specially trained to provide practical solutions to industry's most complex casting problems.

Upon request, we'll send the complete "1948 series" of advertisements...also your copy of Monarch's FACT-FILE for design, production and purchasing executives.

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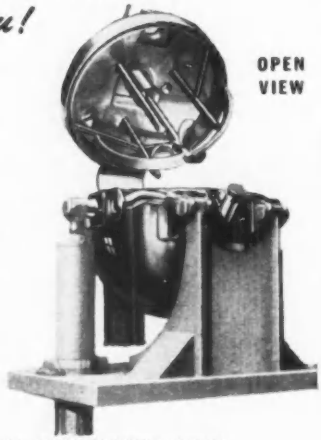
Maybe you'll never need a huge vacuum MELTING KETTLE

but — THE SKILL THAT CREATED IT MIGHT SOLVE A PRODUCTION PROBLEM FOR *You!*

When your Defense Contracts or regular productions call for specially built pressure vessels or processing machinery . . . put the problem up to GROEN. For half a century we've been fabricating complicated and simple jobs in Stainless, Nickel, Monel, Everdur, Inconel. We know how. The large Vacuum Melting Kettle above is an example. We produced a quantity of these from bare specifications in record time. Consult us on *your* special jobs. Depend on our ample facilities, long background, engineering skill and financial solidarity to deliver what you want satisfactorily. *Why not write us now?*



WORLD'S LARGEST PRODUCERS OF STAINLESS STEEL STEAM JACKETED KETTLES

Half a Century of Fine Kettles GROEN

GROEN MFG. CO.
4535 W. Armitage Ave., Chicago 39
30 Church Street • New York 7
7 Front Street • San Francisco 11

are readily determined by the equation

$$W = \frac{231 \times 62.4}{60 \times 123} GS$$

which reduced to

$$W = 0.13903\ GS$$

where W is the weight rate of flow in lb per sec, S the specific gravity and G the volume rate of flow in U. S. gal. per minute.

—NILS M. SVERDRUP

Aerojet Engineering Corporation

Ed—Flow chart was not reproduced on 20-divisions-to-the-inch graph paper in order that our readers might have a more legible and easier-to-read chart to study.

Facts and Figures Work Here Too

To the Editor:

Your editorial "Shall It Be A Job For The Engineering Societies?" and the numerous replies in your December issue indicate a wide spread interest in the most important question facing the citizens of this republic.

It is certainly a job not only for the engineering societies but for every professional society and every other organization that can reach the ear of the public.

But it will do little good to fume and sputter about the situation that confronts us. Instead we should have some hard, cold facts to present just as we use facts and formulas as the basis of the engineering profession.

Can our congress reduce the national budget? Twenty minutes spent in reading Senator Harry Byrds factual analysis of this subject gives you the answer.

Has communism infiltrated into our churches schools and colleges? John Flynns book *The Road Ahead* gives names, dates and places that disclose how far leftist teachings have reached to accomplish this.

Do book reviewers give liberal and leftist books a boost and omit reviews or discredit books on private enterprise and our present form of government? Read Irene Kuhn's pamphlet published by the American Legion entitled *Why You Buy Books That Sell Communism* and you will have plenty of ammunition to answer that one.

The Freeman Magazine and the Spotlight news letters, both published in New York, contain only powerful condensed articles on all the forces attacking our country both here and abroad. They should be read by every person who sincerely desires to expose and discredit the propaganda and peo-

ACEC

Adjustable Speed Induction Motor

Simplifies operation and minimizes maintenance

Here is the ideal low cost solution to the problem of adapting A.C. motors to the job of driving machines which must be operated at variable speeds: The ACEC Schrage-type Adjustable Speed Induction Motor—a rugged, compact, self-contained unit—permits a range of speeds from 0 to 2400 RPM. at the turn of a knob. With the standard type, it is possible to vary the speed from 600 to 1800 (1:3) and from 0 to 2400 RPM.

The motor is designed to work at constant torque and adjustable speeds. At full load, its power factor is always near 1, and thus its use can improve the power factor of a whole plant.

Produced by up-to-the-minute manufacturing techniques which not only assure mechanical precision but minimize production costs, the ACEC "Schrage" affords the most *efficient, simple,* and *economical* means of powering machines that require variable speed drives. It is used extensively in the textile field, and is proving indispensable for numerous applications in the chemical and paper-making industries. Its wide adaptability is evidenced by the fact that it provides the perfect prime mover for such diversified mechanisms as machine tools, variable belt conveyors, automatic stokers, and calenders of different types.

Profit by learning all about the ACEC "Schrage". Write, wire or telephone the nearest ACEC office or representative—or communicate directly with us in New York. We'll be glad to supply you promptly with a complete technical bulletin.

The Schrage-type motor: A rotor winding, similar to that of an induction motor, is connected through slip rings to a 3-phase supply. Brushes, on a commutator connected to a "regulating" winding on the rotor, are connected to electrically separated phases of the stator winding. Changing the position of these brushes, by turning a knob, or by servo-motor with remote control, gives variation in speed.

Integral Horsepower Electric Motors in the following types FULLY GUARANTEED:

- ★ **Adjustable Speed Schrage Motors**
- ★ **Open Drip Proof Motors**
- ★ **Totally Enclosed Fan Cooled Motors**
- ★ **Pump Motors:**
  - Style "C" Face Mounted
  - Style "P" Vertical Solid Shaft
  - Vertical Hollow Shaft

MOTORS EXCEEDING 200 HP. BUILT TO ORDER

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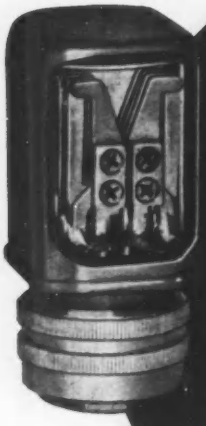

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Now Hermetically Sealed

HUNDREDS of thousands of R-B-M telephone type relays saw Government service in World War II. Now most of these relays are available in hermetically sealed enclosures designed to meet AN specifications.

R-B-M hermetically sealed telephone type relays are available in contact forms up to and including 4-pole, double throw, 3 ampere, 28 Volts D. C. construction. Also 10 ampere rating up to and including 2-pole double throw at 28 Volts D.C. All relays available with approved AN plug connector, or with solder connections.

Engineers! What is YOUR hermetically sealed relay requirement? R-B-M is developing new and smaller relays to meet Armed Services requirements. Perhaps one of these will solve your problems. Write giving complete relay specifications, application, quantity and AN specifications applying. Address Dept. C-3.

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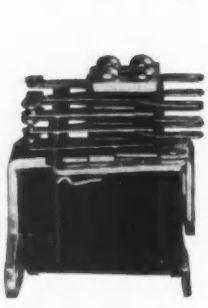

R-B-M Production and Engineering facilities in two plants, located in different states, (over a quarter million square feet), can assist you in the development and production of special electro-magnetic devices for Armed Services application.

RBM

R-B-M DIVISION
ESSEX WIRE CORP.
Logansport, Indiana

MANUAL AND MAGNETIC ELECTRIC CONTROLS
—FOR AUTOMOTIVE, INDUSTRIAL, COMMUNICATION AND ELECTRONIC USE

ple whose main purpose is to push this country into socialism.

If we do not get into this scrap in a positive way, and soon, we will leave a sorry heritage to the generation that fought a global war and is still fighting that this country may retain its ideals of freedom and liberty.

—J. B. FISHER
Waukesha, Wisconsin

Ed—An excellent suggestion to get the ball rolling.

Where Can I Get It?

Charged Paint

To the Editor:

Your issue of PRODUCT ENGINEERING for November, 1951, Technical News lists a new electrostatic paint spraying process by the Ransberg Electro-Coating Corporation.

We are very much interested in this process and we would appreciate it if you would forward our request for more information to the Ransburg Electro-Coating Corporation whose address we do not know. —H. SOLOMON
Home Steel Products Ltd.

Ed—The Ransburg Electro-Coating Corp. is located at 1234 Barth Ave., Indianapolis 7, Indiana. You should get in touch with Mr. R. H. Stone, Sales Manager at that address.

High Speed Computer

To the Editor:

In the December 1951 issue of PRODUCT ENGINEERING on page 186 you mention a high-speed all electronic computer manufactured by the Jacobs Instrument Co. We are interested in obtaining more information on this device and would appreciate having the address of this company.

—OREN G. RUTEMILLER
Morton Manufacturing Company

Ed—The Jacobs Instrument Company may be reached at 4718 Bethseda Avenue, Bethseda 14, Maryland.

Powder Metallurgy Info

To the Editor:

We are very anxious to obtain the latest information on Powder Metallurgy. That means the whole process of making powdered metal parts. If you have any late publications on this

subject, please advise what they are, the names of such publications, and the cost. —CARL BRAMMING
Aladdin Industries, Incorporated

Ed—For the best background material on this subject, we suggest the book entitled "Powder Metallurgy" by John Wulff, published by the American Society for Metals, Cleveland, Ohio.

There have been several recent articles in various publications, and we suggest that you contact the Metal Powder Association, 420 Lexington Ave, New York 17, N. Y. for a listing. You might also request from them copies of the proceedings of their last few annual meetings. Incidentally, one of these meetings will be held in March, and you or one of your associates might attend this meeting. The company exhibits and publications and the opportunity of associating with leading men in the powder metallurgy field should prove of value to you.

Plastic Motor

To the Editor:

We are interested in the small plastic molded electric motor described on page 195, Technical News Section of the PRODUCT ENGINEERING magazine, January, 1952, issue.

Would you please furnish us with the address of the El Ray Motor Company? —R. E. MAPLES
Ciro Cameras, Inc.

Ed—El Ray Motor Company, Inc. is located in North Hollywood, California. Molding material was supplied by Plaskon Division of Libby-Owens-Ford Glass Co., Toledo, Ohio; and complete information is available from Mr. Wyatte Hicks of that company.

Three-Dimensional Plastic Nameplate

To the Editor:

We noticed with considerable interest the article in your December issue of PRODUCT ENGINEERING entitled "Selecting Organic Coating for Metal Products." We are particularly interested in that part relating to three-dimensional plastic nameplates as illustrated on page 175. We have made repeated efforts to locate a source of supply for nameplates of this type and as yet have been unable to find anyone familiar with this process.

We would appreciate it very much if you could supply us with the names of those firms that are presently pro-

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Engineered for your specific sealing requirements

There are no "standard" packings or oil seals in the complete Trostel line—only standard sizes. The seal itself . . . in leather or synthetic rubber . . . is individually developed for the requirements of each specific application . . . by one or more of three separate and distinct Trostel laboratories.

Working closely with the laboratories, the Trostel tool room designs and builds the tools which make it possible to retain *in production* the special properties and tolerances originated by the laboratories and pilot plant.

Modern production machinery . . . specially designed to permit *full automatic control* of critical time, pressure, and temperature cycles . . . provides further assurance of consistent quality.

We invite your inquiry.

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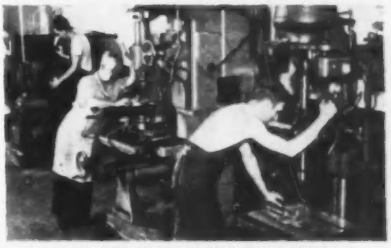
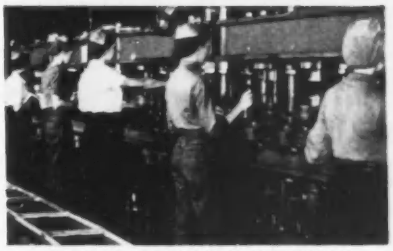

COMPLETE TOOLING FACILITIES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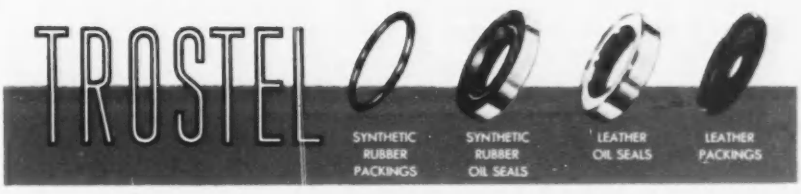

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B BETTER PRODUCTS AT LOWER
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A Quality Product

A Gasoline
Tank Filler Tube

ROUND
3/8" to 4" O. D. 9 to 22 gauge
SQUARE-RECTANGULAR
1/2" to 2" 20 gauge, 1" to 2 3/4", 14, 16, 18 gauge
Carbon 1010 to 1025

Michigan Tubing
has uniform strength, weight, ductility, I. D. and O. D., wall thickness, machinability, and weldability. It can be flanged, expanded, tapered, swaged, beaded, upset, flattened, forged, spun closed, fluted, and rolled. Available in a wide range of sizes, shapes and wall thicknesses, prefabricated by Michigan or formed and machined in your own plant.

For automobiles is just another of hundreds of difficult tubing fabrications manufactured in large quantities and at low cost by Michigan for its customers.

The overflow pipe is brazed to the filler tube at two points and the fastener clamps projection welded to the tube. The cam is spot welded to the tube mouth.

If you have not yet examined the possible adaptability of welded steel tubing to your product, Michigan engineers will be glad to discuss with you the many advantages of design simplification, production savings and product improvement made possible by the use of Michigan tubing.

Consult us for engineering and technical help in the selection of tubing best suited to your needs.

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ducing nameplates which were illustrated in this article. —DICK WILLARD
Domestic Manufacturing Company

Ed—Here are a few companies that can supply this type nameplate: Kent Plastics, Evansville, Indiana; Erie Resistor Corp., Erie, Pennsylvania; General Products, Central Falls, Rhode Island; Santay Corp., Chicago, Ill.

Mail Finds a User For Plastic Diaphragm Material

To the Editor:

On page 268 of the December 1951 issue of PRODUCT ENGINEERING, you published a letter from George T. Metcalf, George T. Metcalf Co. stating that he had a client who manufactured a plastic material which he believed to be superior for use as a diaphragm.

I have a client who I am sure would be interested considering any exceptional material of this type. Will you, therefore, please request Mr. Metcalf to communicate with me or give me the address of the George T. Metcalf Co. —JOS. L. GILLMAN, JR.
Aldie, Va.

Ed—The George T. Metcalf Co. can be reached at 68 South Main St., Providence, Rhode Island.

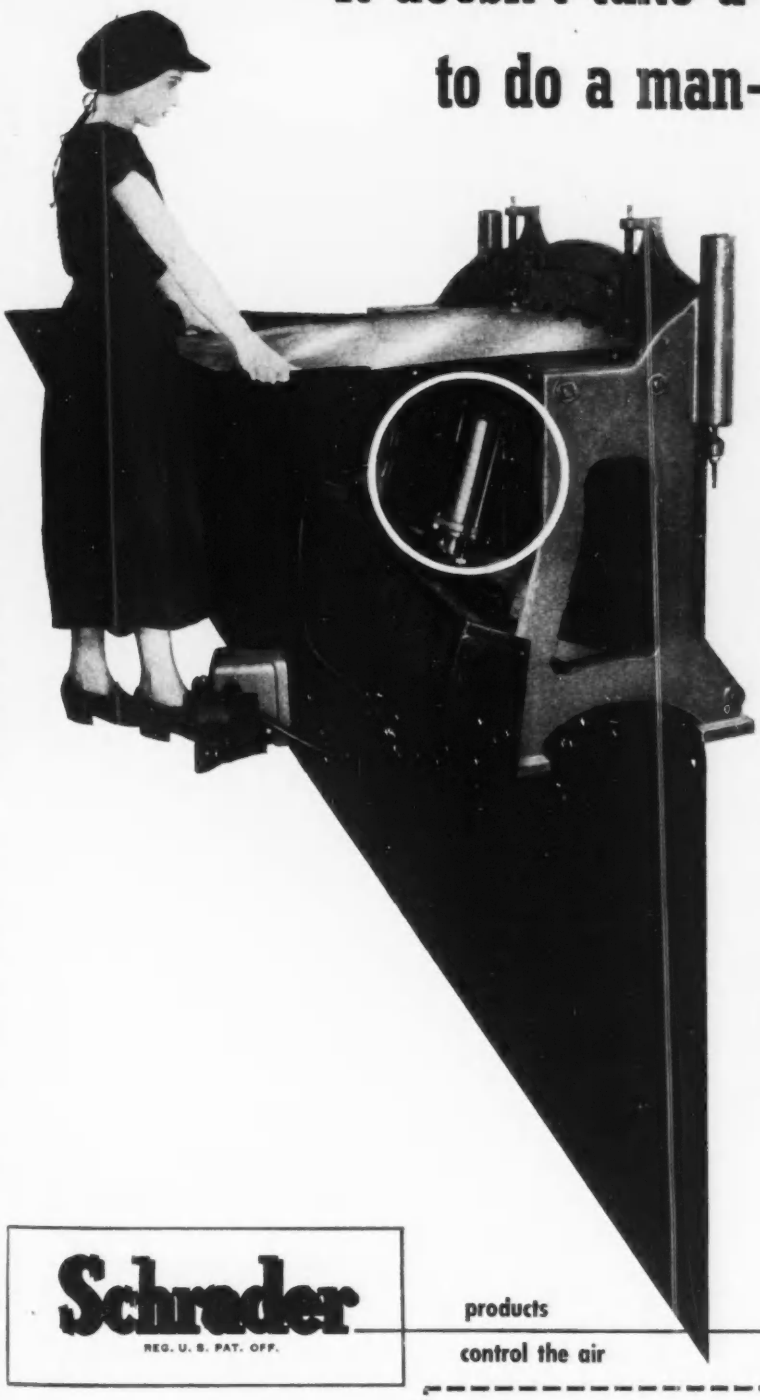
ERRATA

Oct., 1951 Page 126. *How to Tackle Materials Substitution.* The statement ". . . for example, the specifications on low temperature impact properties of armor plate for the tanic program requires the use of steels with nickel content of four- to five-hundred percent greater than during the last war . . ." is incorrect. Low alloy steel compositions developed for armor during World War II are being used today with few modifications.

Nov., 1951 Page 144. *Preplasticizer Triples Capacity of Molding Press.* The credit line under the cutaway drawing of the Watson-Stillman press was inadvertently omitted. This illustration was supplied through the courtesy of the Socony Vacuum Oil Company.

Dec., 1951 Page 222. *Laminated Washer of Metal and Neoprene.* Sentence ". . . Neoprene composition ranges in thickness from 1 1/46 in. to 1/4 in., as specified . . ." should read ". . . Neoprene composition ranges in thickness from 1/16 in. to 1/4 in., as specified. . ."

It doesn't take a heavyweight to do a man-sized job



Before these shears were shifted to air operation the entire weight of a man was required on the foot treadle to cut the sheet metal.

All this is changed now. A light touch of the girl's foot on the pedal puts all the power of the Schrader Air Cylinder to work, sending the knife-edge through the metal.

This is just one example of how air cylinders can speed up production and reduce fatigue . . . one of many hundred applications of Schrader cylinders and valves. It will pay you to design your controls around Schrader air cylinders and valves.

To find out how Schrader air control products can be put to work . . . to boost production . . . lessen operator fatigue . . . increase safety . . . send us a letter outlining your particular requirements, your idea or fill out the coupon below.

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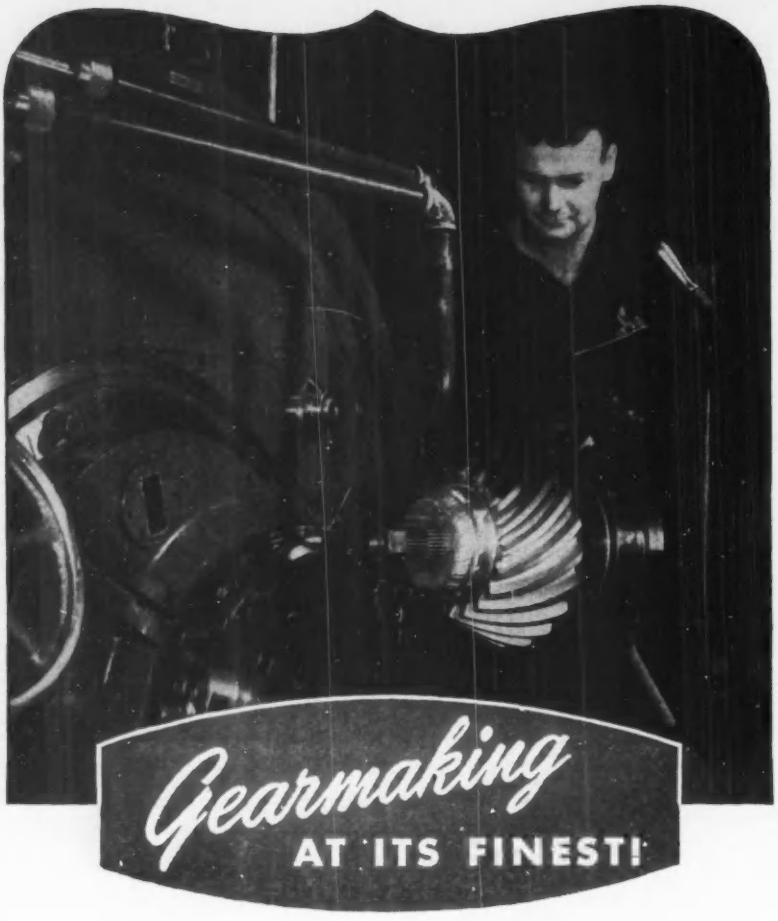


HERE "under one roof" at FAIRFIELD is *everything* needed for producing fine gears — metallurgical department, batteries of the most modern machines, testing laboratories, complete heat-treating facilities — all operated by skilled craftsmen working under expert engineering supervision. By specializing exclusively in "FINE GEARS MADE TO ORDER" for more than thirty years, FAIRFIELD has become one of America's largest producers of these parts. This is why many makers of construction machinery . . . agricultural implements . . . machine tools . . . military equipment . . . tractors, trucks, and buses now regularly depend on FAIRFIELD to meet their requirements. *For the Best in Gears, Specify Fairfield!* FAIRFIELD MANUFACTURING CO., 313 So. Earl Ave., Lafayette, Indiana.

NEW BOOKS

Handbook of Dangerous Materials

N. IRVING SAX. 848 *pages. Published by Reinhold Publishing Corp.* 300 *W 42nd St., New York, N. Y.* $15.

Covering over 5,000 hazardous industrial materials, this complete reference book offers information of utmost value to those concerned with safety handling, storing or shipping chemicals and other dangerous items. These materials, including trade name products, are alphabetically arranged, cross referenced indexed.

Information about each material includes maximum allowable concentration, toxicity, flammability, storage and handling, physical properties, formulas and shipping regulations. Wherever possible, detailed information is given on symtoms, treatments and antidotes, first aid suggestions, personnel safety precautions, fire extinguishing agents and other pertinent data. The complete text of the Interstate Commerce Commission Shipping Regulations is included for detailed instructions on labeling, packaging, storage, shipping and all relevant subjects.

This book also covers the fields of explosives, fungus infections and radiation safety. For chemical toxicology and fungus hazards, the most up-to-date references available are given in every case. In the section on radiation and radiation hazards, there is presented all the most recent data available and many fundamental concepts.

The range of readers who will find this volume valuable in their work includes safety engineers and inspectors, industrial physicians and foremen and plant managers. It is also intended for research and development laboratories and pilot plant workers who use a wide variety of these dangerous material in their daily jobs.

Aircraft Jet Powerplants

FRANKLIN P. DURHAM. 326 *pages. Published by Prentice-Hall, Inc. New York.* $6.65.

Although written primarily as a text for junior and senior undergraduate courses in aircraft jet powerplants, this book is valuable to engineers and designers desiring basic information in this field. A knowledge of elementary thermodynamics and fluid mechan-

ics is essential for thorough understanding of the material in this volume. Knowledge of aerodynamics is not essential, though desirable.

Special emphasis is placed on the gas turbine. The first six chapters of this book offer a short basic course in jet-propulsion and gas turbine principles. Chapters 7 to 11 present a more detailed study of jet-engine components—diffuser, compressor, combustion chamber and jet nozzles. Chapters 12 and 13 cover the fundamentals of ramjets and rockets.

The theory of compressible gas flow is developed throughout the book where its application is necessary, rather than having one full section devoted to it. This allows the reader to see the direct application of the theory to a practical problem and also to see that the theory is necessary to the solution of the problem.

Numerous examples have been included to illustrate the application of the material presented and to serve as a guide to the solution of the problems presented at the end of each chapter.

Fundamentals have been stressed at the expense of mechanical and design details, although many photographs and sketches have been included to acquaint the reader with the general characteristics of the various engines and components mentioned.

Simplified Mechanics and Strength of Materials

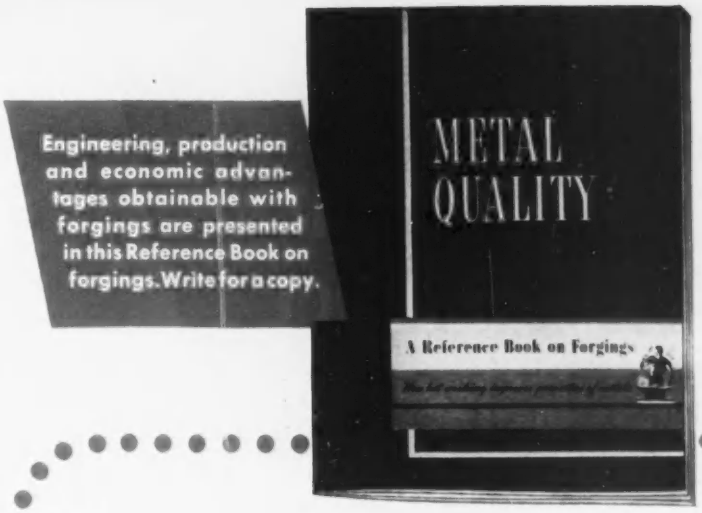
HARRY PARKER, *M. S.*, 275 *pages*, 6 x 9 *in. Published by John Wiley & Sons, Inc. 440 Fourth Ave., New York 16, New York. $4.*

This book is an elementary presentation of the basic principles of mechanics and strength of materials. No advanced mathematics or physics are required for understanding its contents. A working knowledge of algebra and arithmetic are all that is required for a thorough comprehension of the mathematics involved in this volume.

The fundamental concepts of force, velocity, and stress and their application to structural design are presented in a comprehensive manner.

One of the most important features of this book is a detailed explanation of numerous illustrative examples. In so far as possible these examples relate to problems encountered in practice.

Tables of allowable stresses, properties of sections and other engineering data are included for the convenience of the designer of structural members.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Please send 60-page booklet entitled "Metal Quality — How Hot Working Improves Properties of Metal", 1949 Edition.

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One week delivery on intricate electrical assemblies is big news these days . . . but it's *typical* Riverside service! Take this special wiring harness for military electronic equipment, for example. Initial production was actually in our customer's hands just *4* days after we received his prints! And subsequent orders indicate complete satisfaction, worthwhile production economies.

You, too, can profit by using Riverside wiring harnesses on your electrical assemblies! They're neat "packaged units" . . . engineered for quick, easy, accurate installation by relatively unskilled labor. They streamline your product . . . often improve its appearance . . . and they eliminate the need for specialized manufacturing facilities.

So, if wiring installation is keeping your costs up and your production down, take advantage of our specialized experience. We've "harnessed" tough wiring problems for many prominent manufacturers . . . and we can do the same for you! Just send us prints or detailed product information. You'll get prompt engineering and production recommendations, a firm quotation . . . and dependable service!

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and no reference books are required.

This book does not present any short-cuts to a knowledge of the fundamental principles of mechanics and strength of materials. There is nothing new in the presentation, since the discussions follow the present-day accepted design procedures. A thorough study of the material in this volume should, however, afford a foundation of practical information as a step to further study.

Engineer's Illustrated Thesaurus

HERBERT HERKIMER. 572 *pages*, 6 x 9 *in. Published by the Chemical Publishing Co., 212 Fifth Ave., New York* 10, *N. Y.* $6.

More than 8,000 illustrations of machine elements and essembled machinery have been collected to help engineers, designers and manufacturers select the machine parts or equipment that is most suitable for his particular purpose.

Although this book primarily consists of sketches with identifying captions, wherever necessary, an explanation of the method by which the machine element accomplishes its particular function is given. An exhaustive index is included to save much page-thumbing.

The list of topics represented in this work include the following: Fasteners; Adjusting Devices; Supports and Structures; Basic Mechanical Movements; Elevators, Derricks, Cranes, and Conveyors; Transmission of Liquids and Gases; Combustion; Prime Movers, Transportation; Industrial Processes; Electrical Appliances; Comfort Heating, Cooling and Air Conditioning, and various others.

Transient Analysis in Electrical Engineering

SYLVAN FICH, *Associate Professor of Electrical Engineering, Rutgers University, State University of New Jersey.* 306 *pages*, 5½ x 8½ *in. Published by Prentice-Hall, Inc., 70 Fifth Ave., New York, N. Y.* $7.35.

This text was written for the purpose of extending transient analysis in electrical engineering to include modern operational methods, without eliminating the presentation of classical theory. This reflects the author's belief that an understanding of both classical and operational methods is an essential component of the training of a modern engineer. The only prerequisites for understanding the subject are the conventional courses

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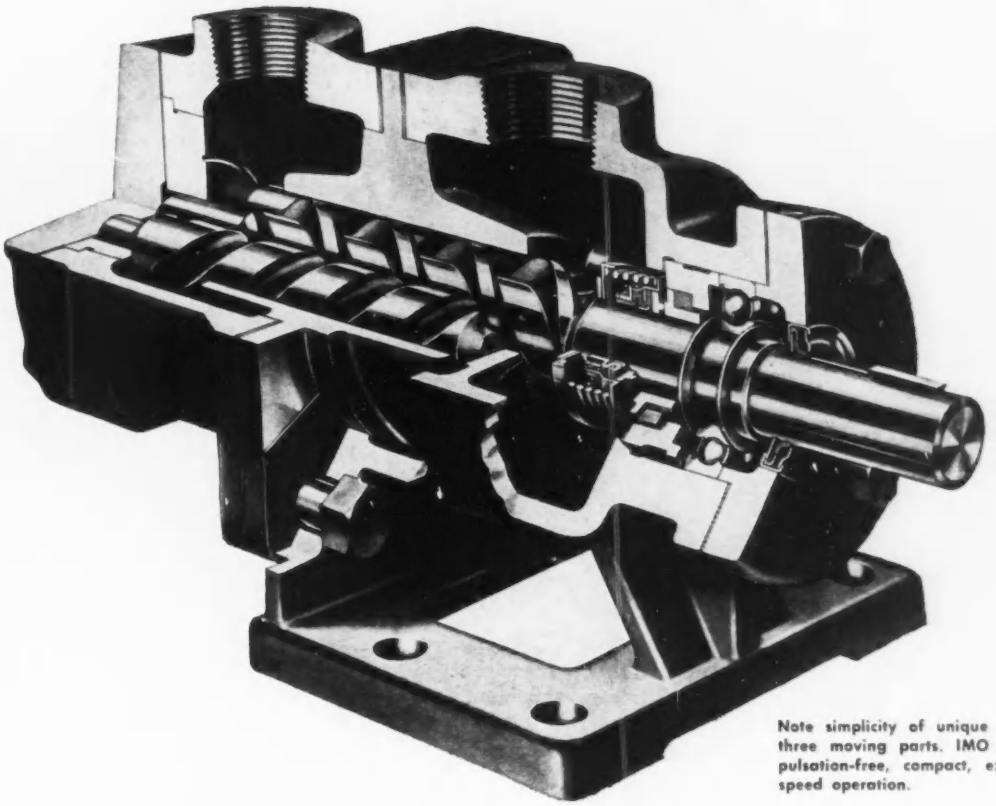

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in calculus, college physics, and steady state circuit theory. Alternating-current circuits can be studied simultaneously with transients, as presented in this text. No previous knowledge of differential equations is assumed.

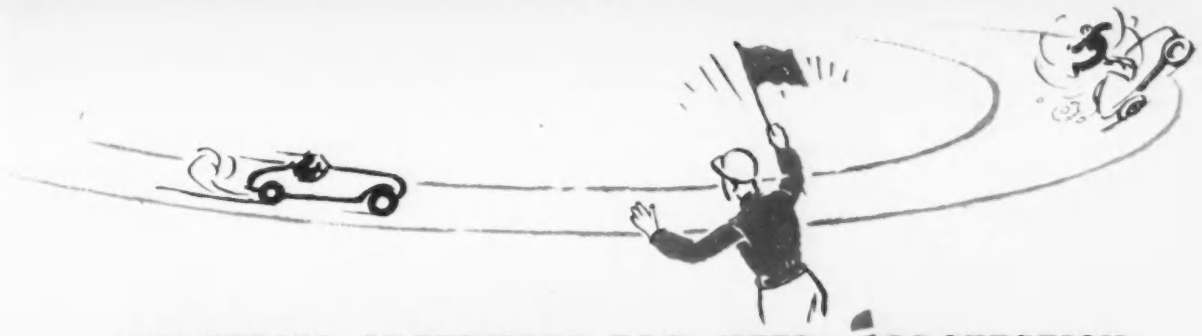
The first five chapters of this book are devoted to the solution of linear differential equations and their application to the classical solution of electrical and mechanical transients. The concept of a complex frequency is introduced by the definition of a complex angle in the classical analysis of an oscillating circuit. The Laplace transform is developed in Chapter 6 and applied to networks in the following chapter. Methods for solving higher-degree algebraic equations are presented in Chapter 8 and applied to circuit problems in Chapter 9. The Fourier series, integral, and transforms are developed in Chapter 10. This is followed by an introduction to complex-variable theory and its application to the calculation of inverse Laplace transforms. Chapter 13 deals with distributed parameters. A resume of electrical analogues of engineering systems is given in the last chapter. An attempt is made to present the physical basis of the mathematical results obtained throughout the text. In addition to a large number of illustrative examples which are completely solved, over two hundred problems, many with answers, are included in the text.

Elias E. Ries, Inventor

ESTELLE H. RIES. 360 *pages*, 5½ x 9 *in. Published by Philosophical Library*, 15 E 40*th St., New York* 16, N. Y. $4.75.

This is the biography of a man, one of America's great inventors, who lived and invented far ahead of his contemporaries. Even the U. S. Patent Office was unable to comprehend his inventive genius so that some of his patents that are the basis of multi-million dollar industries today were refused by the patent office on the first offering because of their "impractical" nature.

While every school child recognizes Bell as the inventor of the telephone, Edison the incandescent lamp and phonograph, and Marconi the radio; many engineers working in the very fields are not acquainted with the name of Elias E. Ries as the holder of basic patents covering: alternating current generation and transmission for Electric Railroads (1890), electric riveting (1891), electric welding and tempering (1887) and the sound motion picture (conceived in 1890; re



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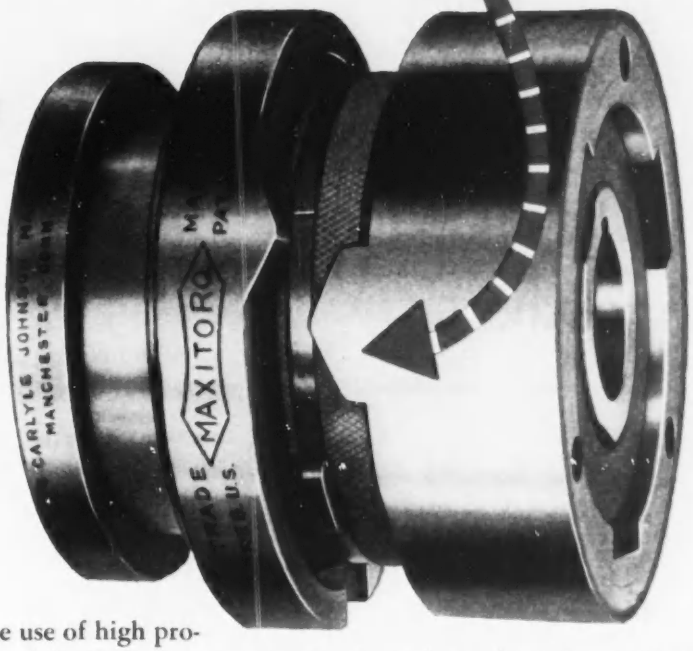

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fused by the patent office in 1913; finally allowed in 1923).

Although written by his daughter who held her father in more than conventional esteem and love, this is not a happy story. For Ries never received either adequate financial compensation or inventive recognition for any of his 200 important basic patents.

Elias E. Ries, Inventor is a chronicle of heartbreak as it records a lone inventor's unsuccessful struggles against monopolies, large corporations, and our antiquated patented system with its terrors of "patent and interference". This 30 year battle proved too much for Ries who died in 1928, absent-minded, poor and unrecognized. Only he and his family were aware of his great contributions to America's industrial development.

Incentive Management

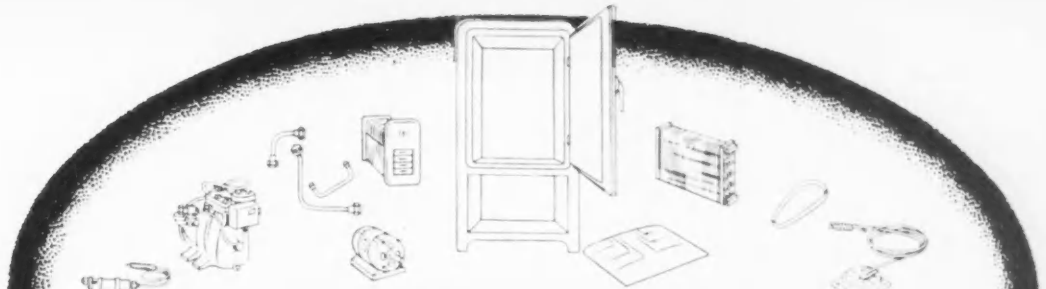
JAMES F. LINCOLN, *president, The Lincoln Electric Company,* 280 *pages,* 5¾ x 9 *in. Published by The Lincoln Electric Co., Cleveland* 17, *Ohio.* $1.00

Everyone who is in any way concerned with the management of human beings, whether it be a group of two or two thousand, will certainly profit from the reading of James F. Lincoln's latest book, Incentive Management. In fact, the title of the book does not reflect its contents. The major portion of the book is devoted to the philosophy of incentive.

James F. Lincoln needs no introduction. His position in the American industrial picture is well established. However, anyone reading this book will be very much impressed by the fact that Jim Lincoln throughout the book takes sides with the employee and severely condenms improper management. There certainly is nothing biased and because the book is so honestly written it is fruitful reading for both employers and employees.

The opening sentence of the book is, "The world is going through a revolution." That immediately establishes the fact that the author is certainly not a reactionary and looks with regrets upon the tremendous progress in science and industry. To the contrary, Jim Lincoln is looking even way beyond the present frontiers. At the same time, there is nothing starry eyed in his principles and recommendations.

On the very proper premise that every man is a product of his determination and opportunities, Mr. Lincoln establishes the premise that incentive is the key to his development; that crises create leaders; and



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that all men have latent abilities. If they be given the incentives to develop these latent abilities the possibilities for progress are unlimited.

Referring to the increased profit that will accrue through the greater efficiency of operations in industry Mr. Lincoln is very emphatic that the customer, worker and owners of the industries must all share in the profits and each to a proper degree. The worker must receive a reward that he feels is commensurate with his contribution.

As Mr. Lincoln points out, any management that operates on this philosophy which he calls incentive management, contributes to guaranteeing the continuation of free enterprise. It points out that profit is not the sole purpose of industry and that the primary goal of industry is to produce more and more at less and less cost. To accomplish this is the responsibility of industry.

The greatest responsibilities must be shouldered by the industrial leaders who must be deserving of their positions, who must respect and recognize the skills of a worker, who can justify the salaries they receive and who are capable of putting the worker under incentive pressure that will stimulate him to develop himself by virtues of the incentives. Skillful management must also control the stock holder so that he will not be too greedy in demanding an excessive portion of the increased profits.

Talking about time study, Mr. Lincoln points out that this is one of the most important activities in manufacturing. Unless the worker himself accepts the piece rate wholeheartedly, the price is wrong. It must be recognized that the worker himself is probably the greatest expert in setting the rates. Emphasis is also put on the fact that a piece price once made is a contract that cannot be broken and it is the time study man's job first to find the best method of doing a good job and then to teach that method.

One chapter is devoted to the subject, "Why Incentive Systems Fail." In this chapter the author management to task rather than blaming the worker. In fact he puts practically the whole blame on management.

Plastic Molding

JOHN DELMONTE. *493 pages. Published by John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, New York.* $9.

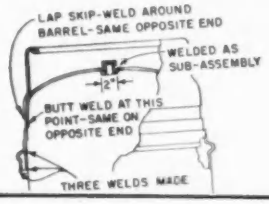
This book covers the process of conversion of organic plastics materials into useful industrial or consumer

Ideas on Welded Design — For the Engineer's Notebook

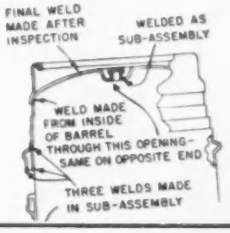
MAKE WELDS DO DOUBLE DUTY

Relocation of a single weld can sometimes turn an impractical job into profitable production. For example, this slight design change simplified jigging and saved excessive fixture and equipment costs. An enlarged tap hole subassembly makes it possible to join chime ring, head, and center section with one mechanized HELIARC weld, made from inside the barrel. One complete welding operation is eliminated at each end of the barrel.

ORIGINAL DESIGN


LAP SKIP-WELD AROUND BARREL-SAME OPPOSITE END
WELDED AS SUB-ASSEMBLY
2"
BUTT WELD AT THIS POINT-SAME ON OPPOSITE END
THREE WELDS MADE

MODIFIED FOR PRODUCTION


FINAL WELD MADE AFTER INSPECTION
WELDED AS SUB-ASSEMBLY
WELD MADE FROM INSIDE OF BARREL THROUGH THIS OPENING-SAME ON OPPOSITE END
THREE WELDS MADE IN SUB-ASSEMBLY

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products. It offers a carefully planned analysis of the plastics molding industry and the equipment used by the industry. The principles and accessory apparatus that permit a molder to attain a high degree of precision and versatility are also discussed. Approaching the subject from an engineering viewpoint, this book considers first the flow of materials and second the techniques for handling the materials once the flow has been properly established.

An introductory chapter discusses the basic commercial plastic molding materials. Subsequent chapters emphasize the selection and adaptation of equipment to molding problems, and show the application of scientific principles to molding processes in a manner that should prove useful to the industry.

The basic types of fabrication techniques are carefully and clearly discussed. These include compression molding, transfer molding, injection molding, extrusion and finishing. The important subjects of heat and pressure generation, distribution and application, instrumentation and plant layout are thoroughly covered in the chapters on pumps, accumulators, valving and heating.

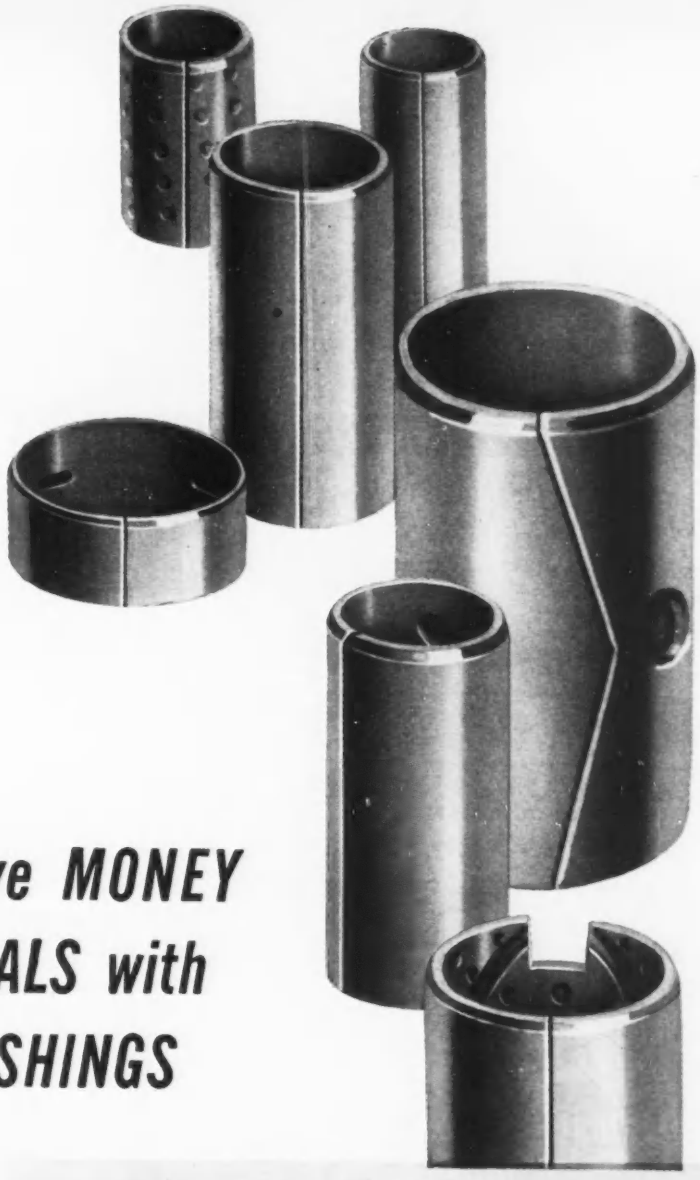
The material in this book has been prepared and presented for use by the plastics engineer and the plant superintendent. An effort has been made to glean the basic principles of molding from the many supporting activities, and to present useful design criteria that should help eliminate the guesswork involved in many molding operations.

The many illustrations and precise drawings and sketches clearly present the details of design and construction of the machines and molds used in plastic processing.

Graphic Aids in Engineering Computation

RANDOLPH P. HOELSCHER, *Prof. and Head, General Engineering Drawing Dept., Univ. of Illinois.* JOSEPH NORMAN ARNOLD, *Assoc. Prof., Purdue Univ.* STANLEY H. PIERCE, *Assoc. Prof. of General Eng. Drawing Dept. and Ass't Dean of Engineering, Univ. of Illinois.* 197 *pages,* 6 x 9 *in. Published by McGraw-Hill Book Co.* 330 *W. 42nd St. New York* 36, *N. Y.* $4.50

Graphical and mechanical aids in engineering computations can often save much valuable time and effort. Therefore, this text was designed for those who wish to attain an understanding of the basic principles and



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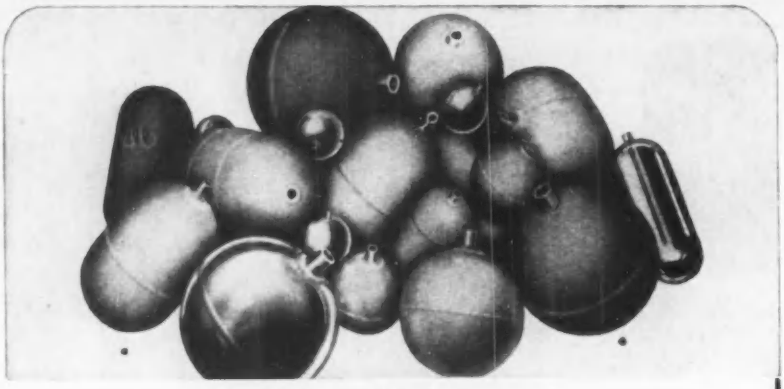

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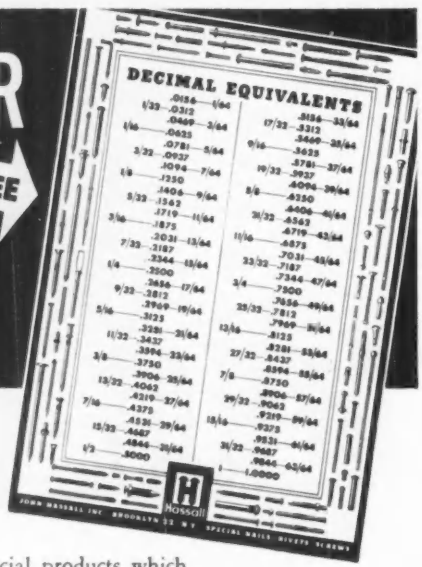

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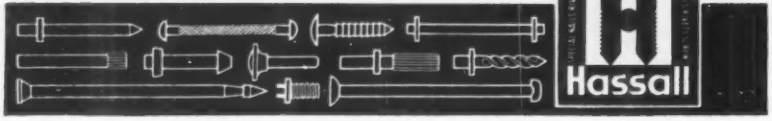

the actual methods of operation of slide rules, alignment charts and other graphical aids.

Since the derivation of emperical equations from experimental data is a very useful tool for those pursuing research work, a chapter on this subject is included. For the same reason, a discussion of graphical differentiation and integration is included.

The text does not purport to offer anything new in nomography. It does, however, endeavor to present many complex problems of construction in a more detailed manner than is usually available. A complete chapter is devoted to the construction of alignment charts by means of determinants.

The discussion of nomographs is also extended to movable-scale types although no attempt is made to present the general theory of these since it is considered unappropriate for an elementary text such as this.

Fundamentals of Automatic Control

G. H. FANINGTON, *Consultant Engineer, Ilford Ltd.*, 285 *pp*, 6x9 *in.*, *Published by John Wiley & Sons, Inc.*, 440 *Fourth Ave., New York, N. Y.*, $5.

Before an engineer can properly apply commercially available control equipment to the everyday plant and process regulation problems, he should have a clear picture of the theoretical principles which affect automatic control applications. This book undertakes the investigation of the basic nature of the problems which may be encountered, rather than specific details of plant or apparatus.

The analysis by which the fundamentals can be reached is greatly facilitated by the employment of mathematical methods. This overcomes the difficulty which arises when endeavoring to visualise the simultaneous behavior of the conditions involved. Accordingly, the author has introduced these methods in a manner which will make them understood by readers not accustomed to their use.

In order to clearly demonstrate certain of the control principles the author has resorted to electrical and mechanical analogies throughout the book. To a person familiar with the properties of electric circuit components this method offers a logical approach to the explanation of certain control circuit phenomena.

Beginning with the consideration of the basic closed book control arrangement, the author reads into a dis-

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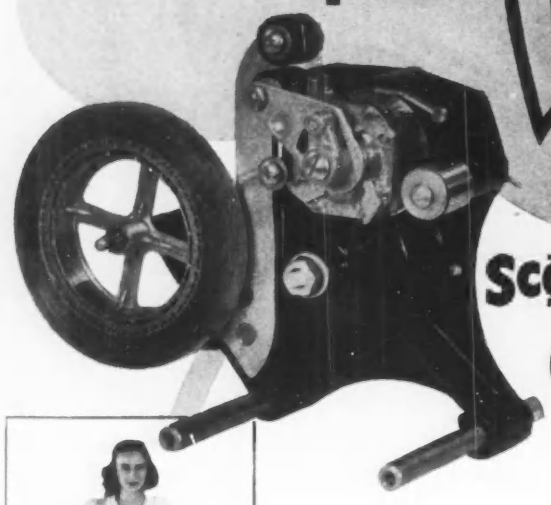
Here's how 13 Twin City Castings prove LUCKY in this SCOTCH BRAND Tape dispenser



13 TWIN CITY CASTINGS USED IN TYPE "M" BOX SEALER

Here was a job that called for *more* than accurate dies and close-tolerance castings. It called for *co-operation* between designer and die caster . . . the kind of cooperation so important to creative manufacture.

Result: an extremely successful manually operated box sealer for use with Scotch brand cellophane tape. The unit is built by Specialty Manufacturing Company for Minnesota Mining and Manufacturing Co., manufacturers of Scotch tape. The dispenser contains 13 zinc die castings from complex main frame to small trip-pin arm . . . all *Twin City* die castings and *Twin City*-built dies.

If you have a particular die casting job, large or small, that calls for "cooperation" with your die caster . . . contact Twin City. Hundreds of manufacturers have found that it pays.

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cussion of the fundamental relationship between the control action of the regulating unit and the modulation which it impresses on the controlling unit. On-off, proportional, integral, derivative, and combinations of these four types of control action are covered.

The factors which affect the transfer of intelligence from one circuit element to another are analyzed using electrical and physical analogies. This section includes the rate of change of one or two variables in the system, circuit oscillations and damping.

After the synthesis of a control system from derived mathematical relationships, the scope of the basic control circuit is broadened to include both demand and supply changes to the controlling unit.

Brief consideration is given to multiple control systems in which the control point of the primary regulating unit does not remain fixed, but is varied in turn by the controlling unit of a secondary control circuit.

Examples are given of several practical pneumatic control elements which respond in a manner approaching that of theoretically perfect controllers, and the book is concluded with a chapter on control selection and adjustment a valuable adjunct.

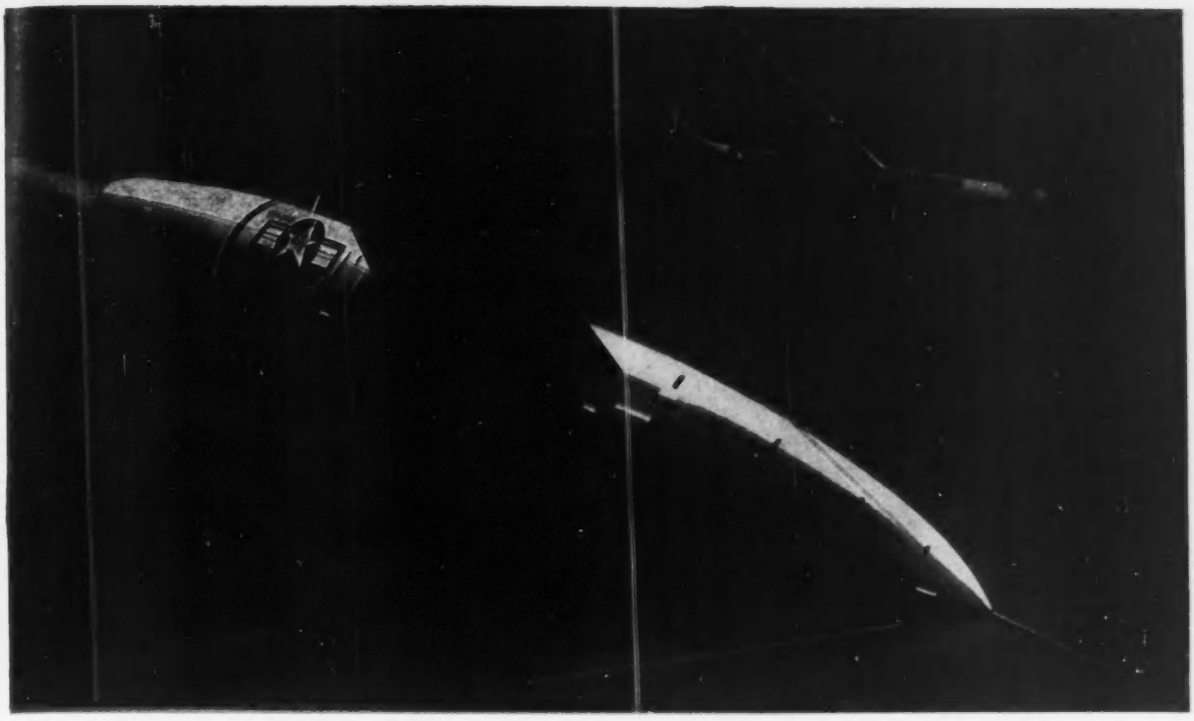
Compilation of Analog Transducers

MARK T. NADIR, *Applications Engineer, Allen B. Du Mont Laboratories, Inc. 68 pp, 8½ x 11 in. Published by Allen B. Du Mont Laboratories, Inc., Instrument Div., 1500 Main Ave., Clifton, N. J., Paper cover,* 50 cents.

This is an easy-to-use reference of transducers for use with cathode-ray oscillographs. The new compilation contains over 500 different types of analog transducers arranged alphabetically according to their functions.

To employ the versatility and accuracy of the cathode-ray oscillograph in the investigation of non-electrical research, development and industry, it is necessary that the effect in question be converted into an equivalent electrical signal by means of an appropriate transducer. Through the use of this compilation the user may find the model, manufacturer, and mechanical and electrical characteristics of the transducer required.

For each transducer, the following pertinent information is given: Function; Principle of Operation; Accessories Required; Transfer Characteristics; Power Required; Amplitude Range; Sensitivity; Output Characteristics; Bandwith; Resonant Frequency;



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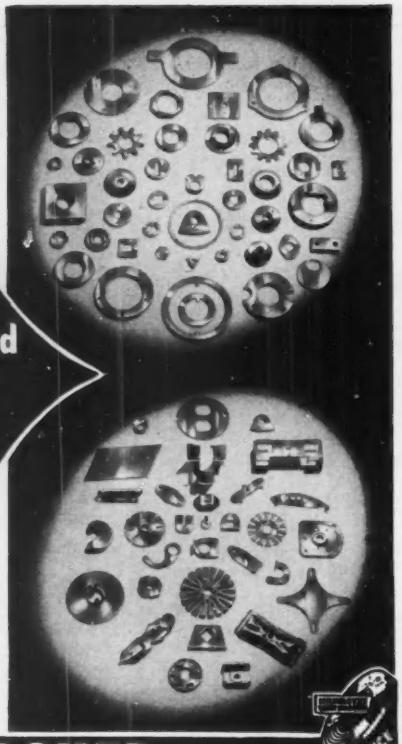

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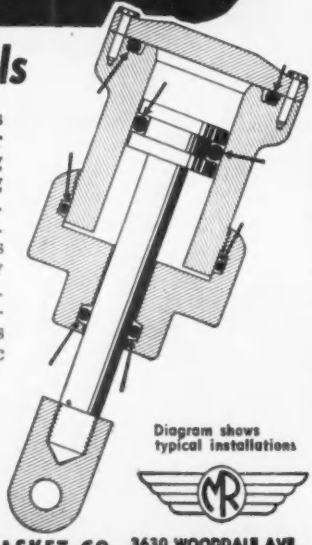

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Resolution or Precision; Linearity, Weight; Range, Sturdiness; Temperature Limitations; Mounting; Size; Remarks; and Model Designation.

For radiation studies, a special section tabulating Geiger-Mueller Tubes is included. A transducer accessory listing has also been included, giving characteristics, remarks, uses, and manufacturer. Another section contains pertinent reference material quoting author and date of publication.

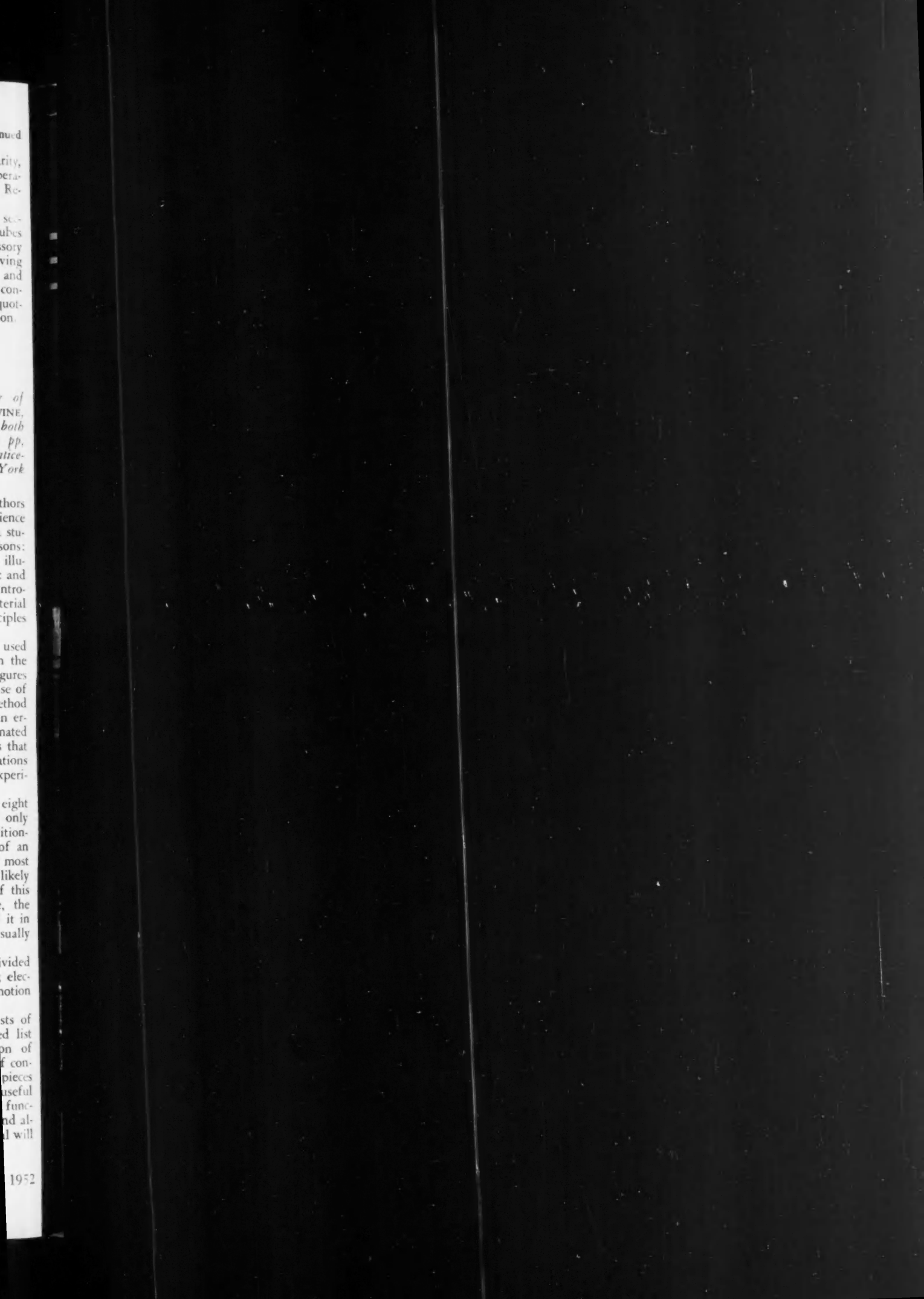
Physics Laboratory Manual

CLIFFORD N. WALL, *professor of physics; and* RAPHAEL B. LEVINE, *research associate in biophysics; both at University of Minnesota.* 232 *pp.* 8½ x 11 *in. Published by Prentice-Hall, Inc., 70 Fifth Ave., New York* 11, *N. Y.* $3.75

In writing this manual, the authors have assumed that direct experience in the laboratory is of value to a student of physics for two main reasons: (1) The results illustrate and illuminate general physical principles: and (2) The laboratory procedure introduces the student to the raw material upon which general physical principles are based.

The method of error analysis used in this manual goes further than the usual reliance upon significant figures alone, but does not involve the use of distribution functions. This method permits the student to compute an error in the result in terms of estimated errors in the measured quantities that yield this result. Error calculations are called for in most of the experiments.

The majority of the seventy- eight experiments described involve only standard equipment and are traditional in character. If the theory of an experiment is readily available in most general physics textbooks, it is likely to be omitted in this manual. If this theory is not readily accessible, the authors have generally presented it in somewhat more detail than is usually done in a laboratory manual.

The body of the manual is divided into five parts: Mechanics; heat; electricity and magnetism; wave motion and sound; and light.

In the appendix, which consists of forty pages, are given a selected list of reference books, a collection of notes describing the principles of construction and operation of many pieces of laboratory equipment, and useful reference tables of mathematical functions and of physical constants and allied data. The user of this manual will find the appendix a definite aid.